

20000  
2M-66

Duplicate

TD  
427  
.H4  
M37  
1984

Maristany, Agustin E.

"

INVESTIGATION OF TEMPERATURE

ANOMALIES IN CHOCTAWHATCHEE BAY,

NORTHWEST FLORIDA /

By Agustin E. Maristany, P.E. and James H. Cason

TD427.14 M37 1984

NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Water Resources Special Report 84-5

September 1984

NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT  
=====

GOVERNING BOARD

Davage Runnels, Chairman  
Destin

William C. Smith, Vice Chairman  
Tallahassee

Marion Tidwell, Sec./Treas.  
Chumuckla

Tom S. Coldewey  
Port St. Joe

W. Fred Bond  
Pensacola

R. L. Price, Jr.  
Graceville

Blucher Lines  
Quincy

Candis M. Harbison  
Panama City

Dr. Louis J. Atkins  
Blountstown

=====  
J. William McCartney - Executive Director  
=====

Northwest Florida Water Management District  
Route 1, Box 3100  
Havana, Florida 32333  
(904) 487-1770

Investigation of Temperature

Anomalies in Choctawhatchee Bay

Northwest Florida

by

Agustin E. Maristany, P.E.

and

James H. Cason

## TABLE OF CONTENTS

	PAGE
Introduction	1
Study Area	2
Hydrology	7
Hydraulics	8
Hydrogeology	10
Occurrence of Anomalous Temperatures	35
Heat Budget	49
Water Budget	55
Development of Study Aspects	59
Data Acquisition	63
Discussion of Potential Heat Sources	75
Summary	80
Selected References	82
Appendix A	85
Appendix B	89

## LIST OF FIGURES

FIGURE	PAGE
1. Study Area Location Map	3
2. Three Dimensional View of The Bathymetry of Choctawhatchee Bay	5
3. Location of Hydrogeologic Cross Sections	13
4. Hydrogeologic Cross-Sections A-A' through D-D'	15
5. Hydrogeologic Cross-Sections E-E' through H-H'	17
6. Map Showing Altitude of the Top of the Pensacola Clay Confining Bed	21
7. Map Showing Thickness of the Pensacola Clay Confining Bed	23
8. Map Showing Potentiometric Surface and Direction of Ground Water Movement in the Upper Limestone of the Floridan Aquifer in March, 1978	25
9. Map Showing Altitude of the Top of the Floridan Aquifer	27
10. Map Showing Mean Chloride Concentrations in Water from the Upper Limestone of the Floridan Aquifer	31
11. Map Showing Mean Sodium Concentrations in Water from the Upper Limestone of the Floridan Aquifer	33

FIGURE	PAGE
12. Location of Monitoring Stations	37
13. Graphical Documentation of Temperature Anomaly	39
14. Areal Distribution of Bottom Temperatures at 8:00 Hours	41
15. Areal Distribution of Bottom Temperatures at 16:00 Hours	43
16. Sections Used in Calculating Heat Budgets	51
17. Location of Data Logger and Mini Monitor	65
18. Major Components of Data Logger	69

## LIST OF TABLES

TABLE	PAGE
1. Temperature and Salinity Profiles at the East Pass	47
2A. Water Budget (Flow)	57
2B. Water Budget (Water Surface Elevation)	58
3. Analyses of Water from Docie Bass Well and from Choctawhatchee Bay	62
4. Data Logger Information Collected near Fourmile Point	71-74

## INTRODUCTION

This report documents the occurrence of a high temperature anomaly in the waters of Choctawhatchee Bay and investigates the potential sources or causes of the hot waters. The study includes general descriptions of the hydrologic, hydraulic, and hydrogeologic settings of the study area; a recount of the high temperature occurrences; a heat budget which quantifies the amount of energy released; a water budget which determines inflow and outflow volumes in the Bay system; a summary and discussion of temperature data collected as part of this investigation; and an examination of the possible sources or causes of the anomalous temperatures.

This investigation was funded, in part, by a grant from the Department of Environmental Regulation, Office of Coastal Zone Management (OCZM) matched by Water Management District funding.

## STUDY AREA

Choctawhatchee Bay is located in the Florida panhandle between longitudes  $86^{\circ}07'30''W$  --  $86^{\circ}37'30''W$  and latitudes  $30^{\circ}30'N$  --  $30^{\circ}22'30''N$  (Figure 1). Its dimensions are roughly 27 miles in length and 4.5 miles in width, extending in a general east-west direction. Its surface area is approximately 120 square miles and the average depth is 15 feet. The Bay is generally shallow at the eastern end with depths averaging eight feet. It deepens progressively toward the west, reaching maximum depths of about 43 feet. Figure 2 shows a three-dimensional view of the Bay's bathymetry. For the purpose of the Figure, depths are shown as elevations above NGVD.

The Bay is relatively isolated from the Gulf of Mexico, except for a narrow opening which allows a small amount of interchange between the two bodies of water. The opening, called the East Pass, is situated in the western end of the Bay. The Bay also connects with West Bay to the east through the Intracoastal Waterway, and with Pensacola Bay to the west through the Santa Rosa Sound.

Choctawhatchee Bay is fed by many small streams at its northern boundary. The largest contributor of fresh water is the Choctawhatchee River which discharges at the eastern end of the Bay. Very little fresh water inflow takes place at the Bay's southern boundary.

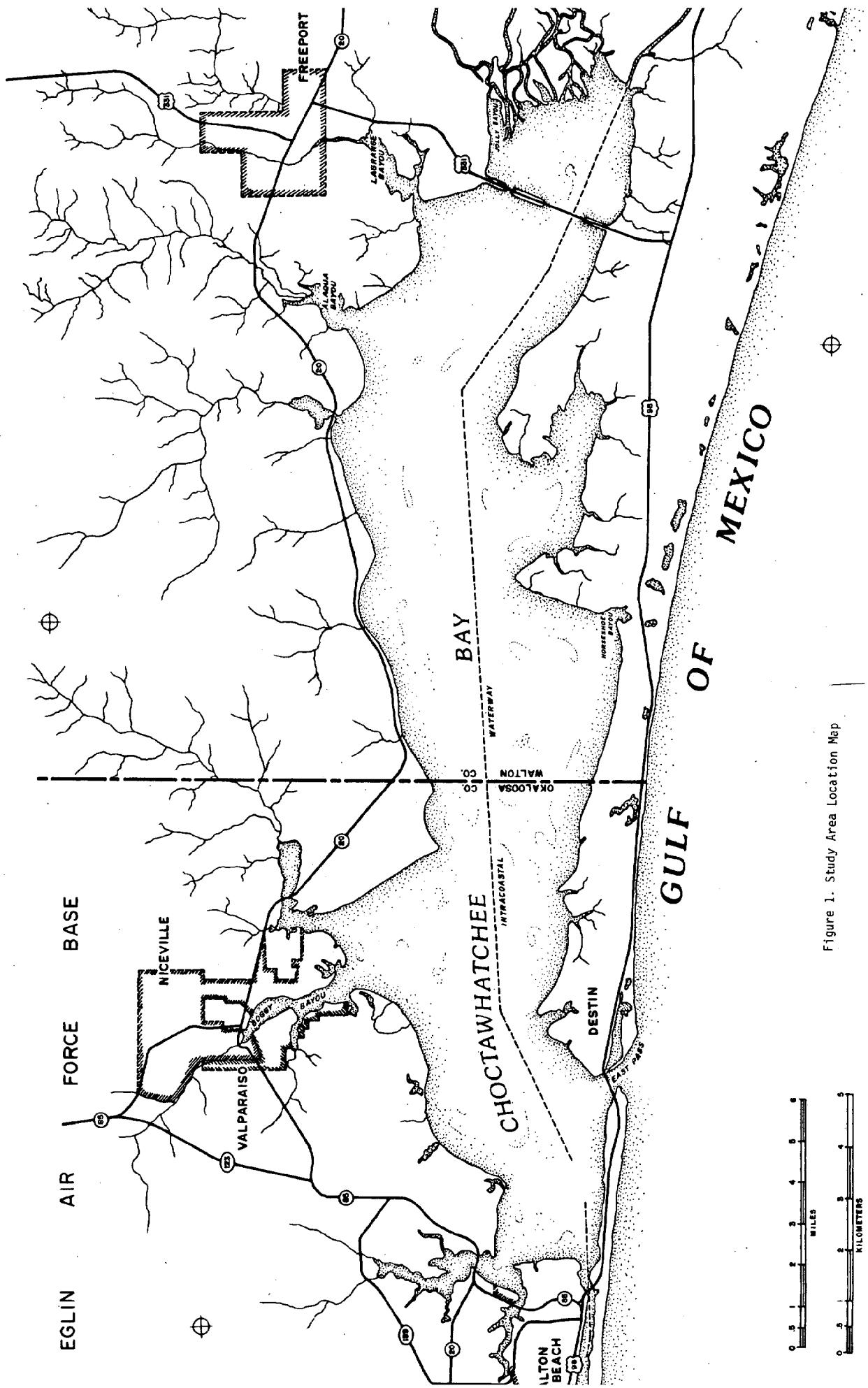


Figure 1. Study Area Location Map

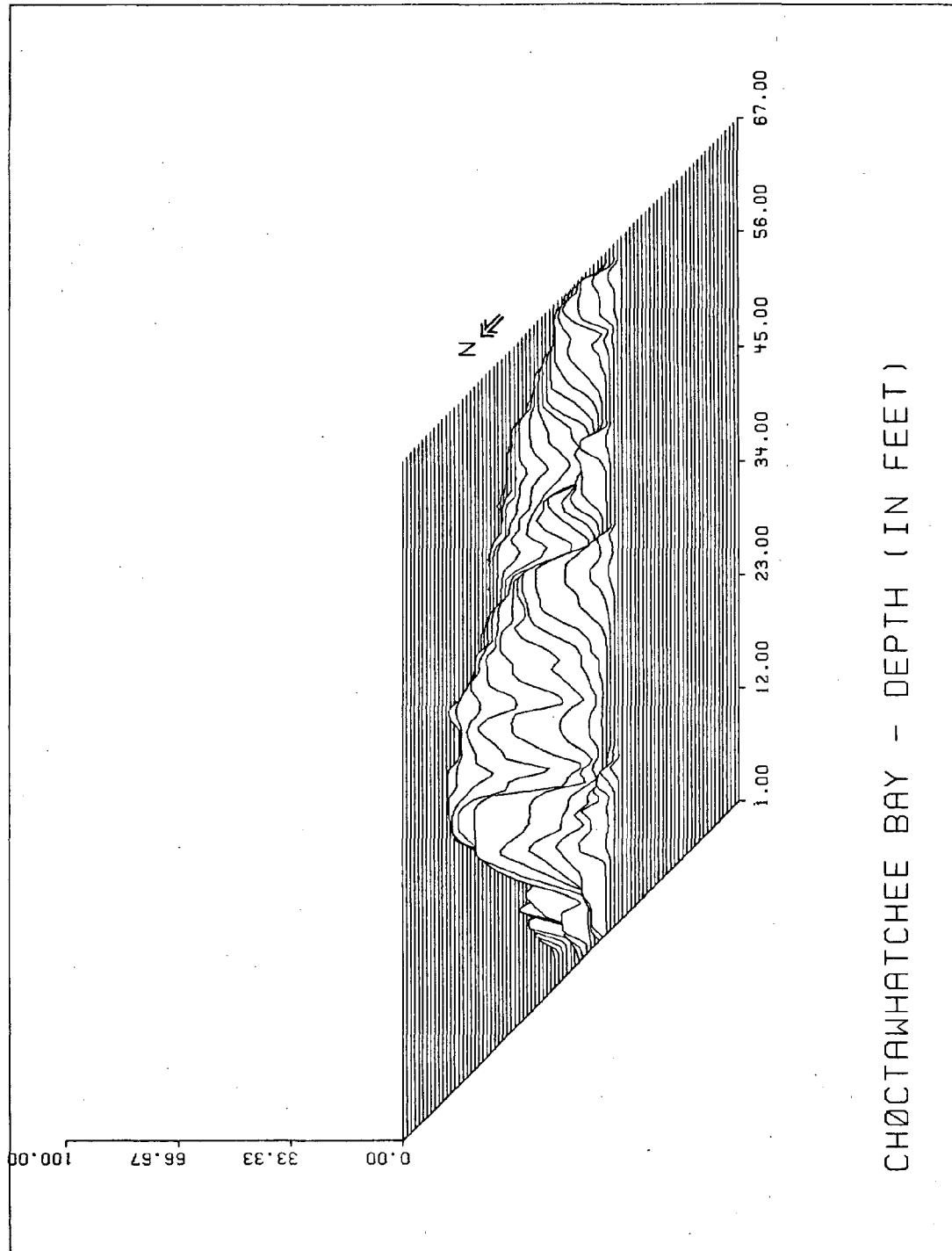


Figure 2. Three Dimensional View of the Bathymetry of Choctawhatchee Bay.

## HYDROLOGY

The total drainage area of Choctawhatchee Bay is approximately 5,338 square miles, of which 85 percent is drained by the Choctawhatchee River. The rest of the basin is drained by several small streams which mostly discharge at the northern end of the Bay. The Choctawhatchee River discharges at the eastern end of the Bay, supplying approximately 85 percent of the total fresh water inflow. Flows at Choctawhatchee River near Bruce, station 02366500, ranged from 1,300 to 76,000 cubic feet per second (cfs) during the period 1930 to 1982. The average flow for that period was 7,164 cfs. In comparison, the total fresh water inflow to the Bay was estimated to average 9,200 cfs.

Tidal flows at the East Pass peak at about 40,000 cfs. In contrast, flows at the Santa Rosa Sound peak at 10,000 cfs, and flows through the Intracoastal Waterway to the east peak at 3,000 cfs.

## HYDRAULICS

Choctawhatchee Bay may be characterized as a "low energy system". This means that river, tide, and wind forces are not strong enough to generate high water velocities. Velocities rarely exceed one foot per second, and the largest velocities occur in the shallow eastern portion of the Bay and at the East Pass and Santa Rosa Sound. Surface velocities are higher than at the bottom with almost no movement occurring in the deepest areas. The tidal range, which is the mean difference between the high and low tides, is approximately six inches inside the Bay, as compared to that in the adjacent Gulf of Mexico which averages about 18 inches.

Circulation in the eastern half of the Bay is primarily dominated by freshwater inflow from the Choctawhatchee River. The river discharges its waters at the eastern end of the Bay, creating a westward movement of the surface waters. This westward flow of fresh water is counter-balanced by a deep eastward current of saline waters which flow under the lighter fresh water. Thus, whereas river water moves toward the Bay at the surface, heavy saline water flows toward the mouth of the river at the bottom. The areal extent of this current loop is dependent upon the magnitude of the river discharge. During average river flows, the loop occurs in the eastern half of the Bay.

As a result of the low energy available to the system, little mixing of fresh and salt water occurs. The fresh water, with a lower density, rests on top of the salt water, separated by an interface zone, the halocline. Stratification is known to prevail in the Bay most of the time, and it is precisely this condition which causes the deep counter currents mentioned earlier. As the river water enters the Bay, it moves over the salt water as a discrete layer at the surface. This movement is accompanied in the denser bottom layer by an opposing counter current. The deep counter current is also called a density current because it is the density differential that imparts its movement.

## HYDROGEOLOGY

Prior to any discussions about the potential interaction of ground and bay waters, it is necessary to develop an understanding of the hydrogeologic setting of the study area. This section presents a brief description of the stratigraphic units of importance, their approximate thickness, water-bearing characteristics, and selected water quality parameters. All information, including the figures, were extracted from the work of Barr, Maristany, and Kwader, 1981.

For the purpose of this section, only the first six major hydrogeologic units occurring in the study area will be considered. These are, in descending order: the sand-and-gravel aquifer, the Pensacola clay confining bed, the upper limestone of the Floridan aquifer, the Bucatunna clay confining bed, the lower limestone of the Floridan aquifer, and the Claiborne confining unit. A series of hydrogeologic cross-sections are shown in Figures 3 through 5. Figure 3 shows the location of section lines, and Figures 4 and 5 illustrate the hydrogeologic sections.

The sand-and-gravel aquifer consists of clean, fine to coarse sands and gravelly sands locally containing silt, silty clay, and peat beds. Regionally, water in the sand-and-gravel is unconfined and in hydrologic continuity with streams and lakes that intersect the water table. For many streams, particularly those that feed the

northwestern end of the Bay, groundwater discharge provides upward of 90 percent of their flows. The sand-and-gravel also discharges into Choctawhatchee Bay, Santa Rosa Sound, and the Gulf of Mexico. In the Coastal Lowlands area, the water table is at, or within a few feet of, land surface. The aquifer ranges in thickness from about 10 feet in south-central Walton County to about 210 feet in southwestern Okaloosa County. Water from the sand-and-gravel aquifer usually has a dissolved solids concentration of less than 50 mg/l, a temperature of 68-77 degrees Fahrenheit, and a PH of 4.5 to 6.5. Iron concentrations average about 0.7 mg/l and chlorides are high in some wells near the coast as a result of saline water contamination.

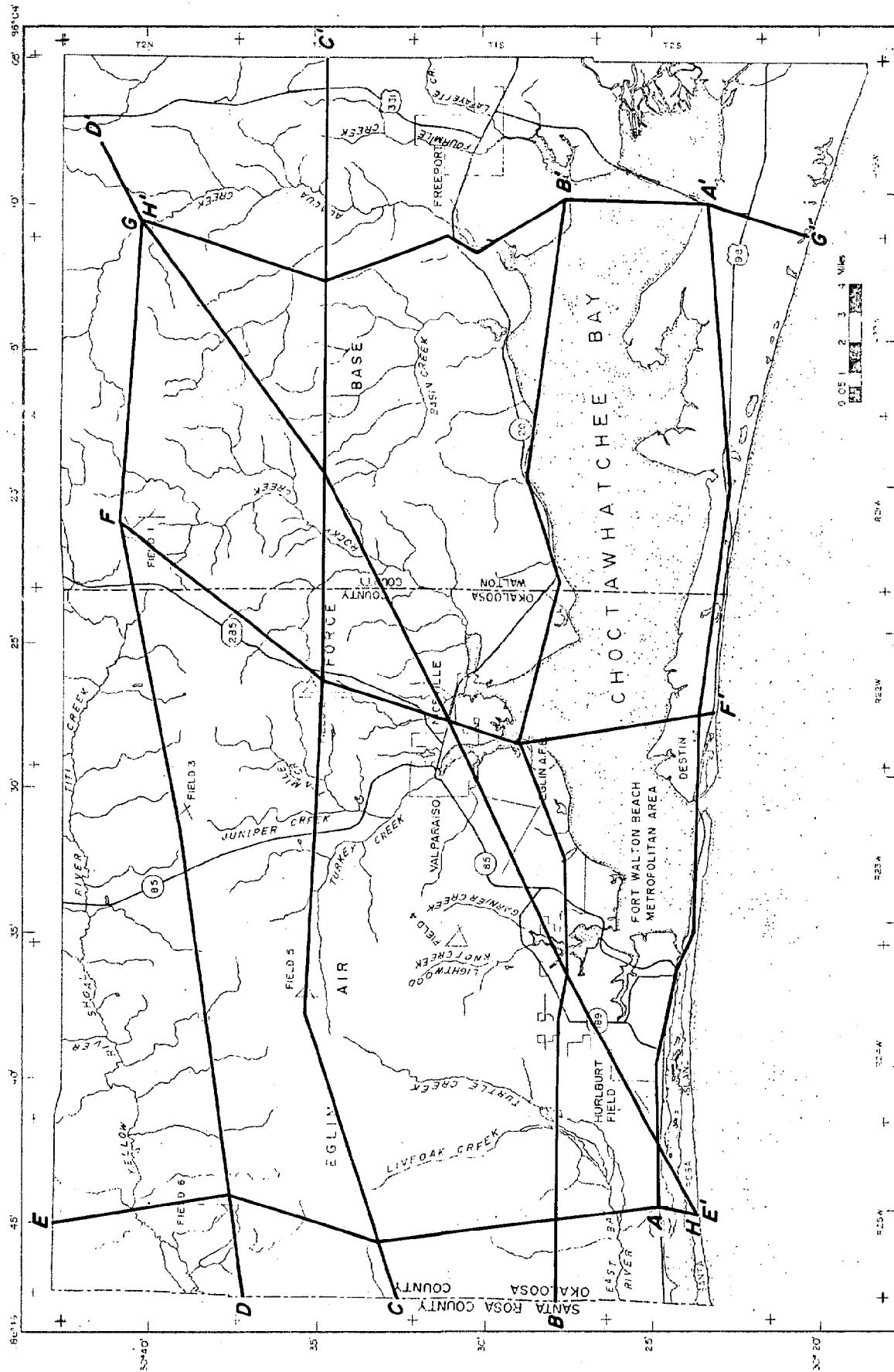
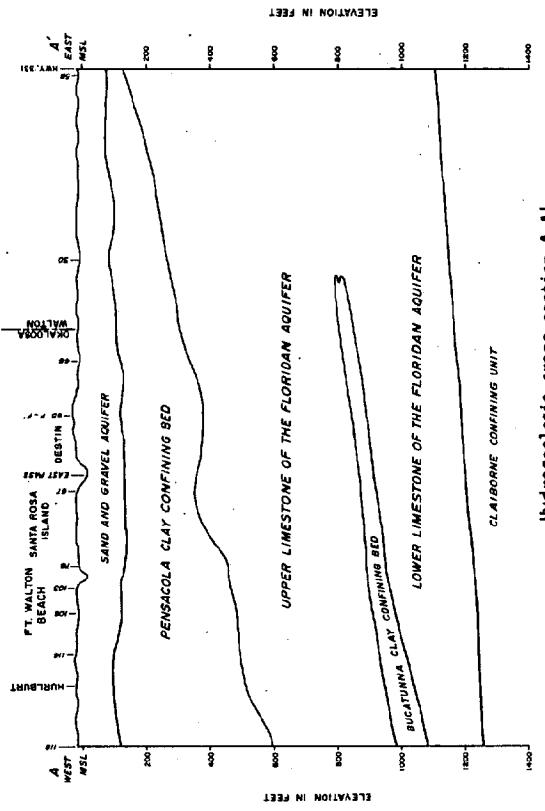
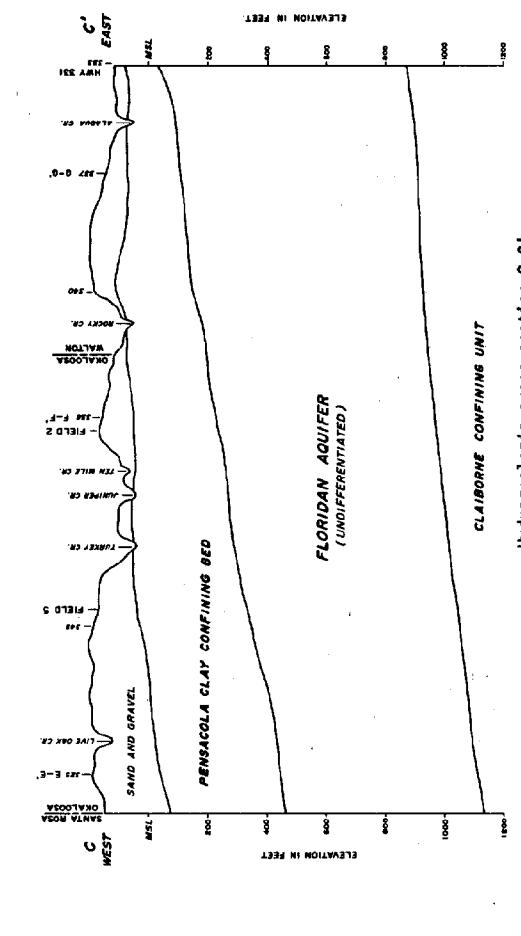


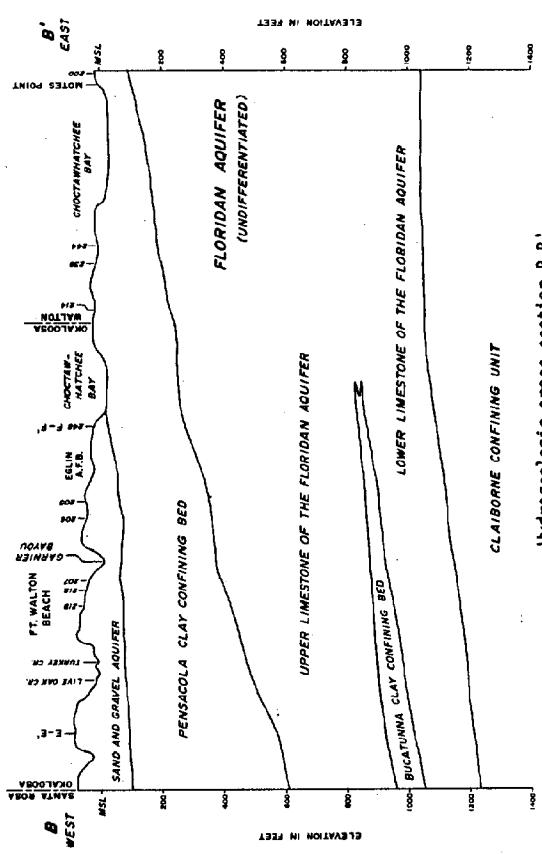
Figure 3. Map showing traces of hydrogeologic cross sections and control wells



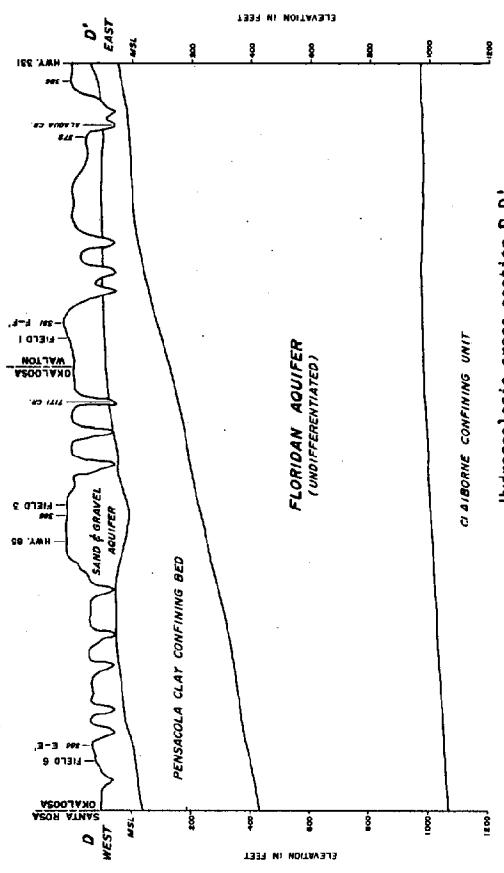
Hydrogeologic cross section A-A'



Hydrogeologic cross section C-C'

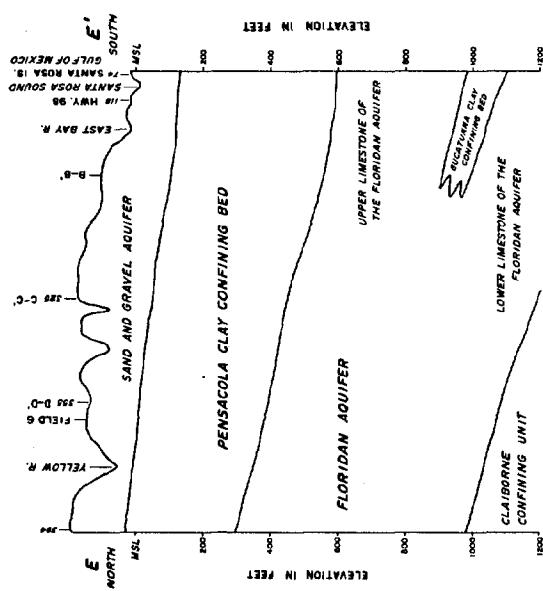


Hydrogeologic cross sections in Northwest Florida (See Figure 3)

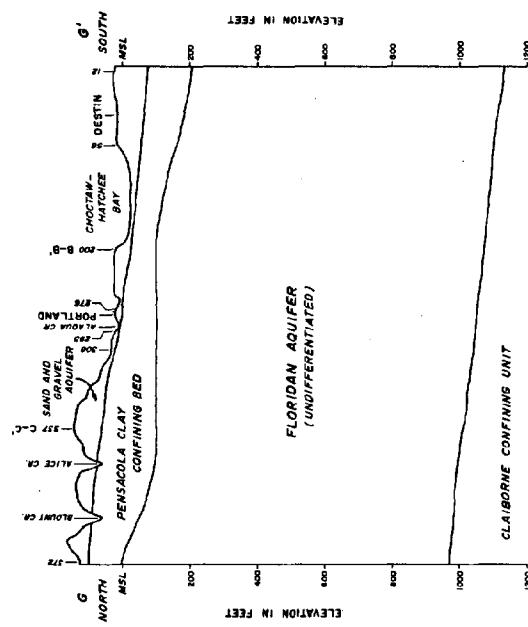


Hydrogeologic cross section D-D'

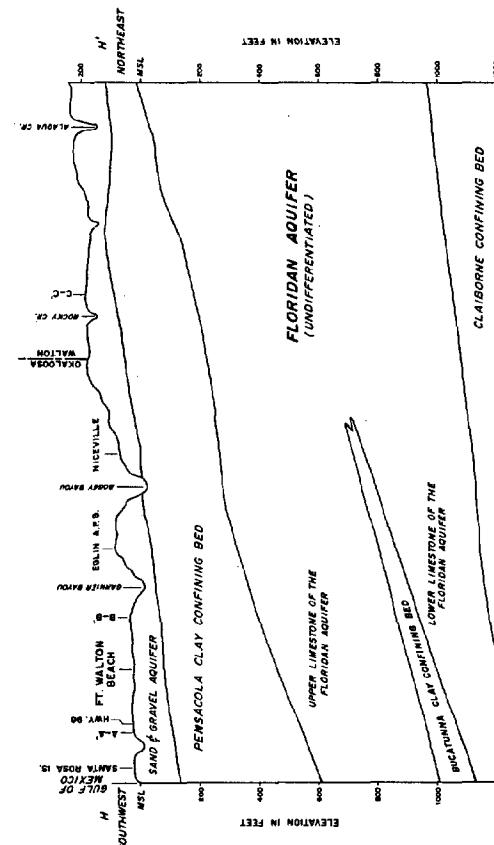
Figure 4. Hydrogeologic cross sections in Northwest Florida (See Figure 3)



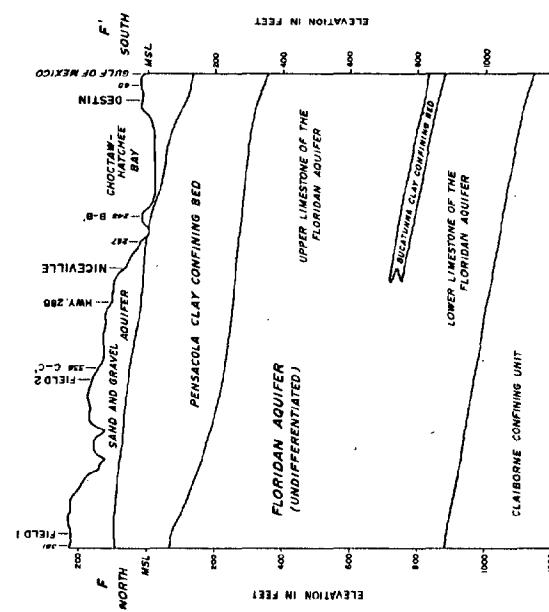
### Hydrogen logic cross section E-E'



### Hydrogen orbital cross section (f-f')



Hydrocarbon accumulation



Hydrogeologic cross section E-E'

Figure 5 Hydrogenous sections in Northwest Florida (See Figure 3)

The Pensacola clay confining bed underlies the sand-and-gravel aquifer in the entire study area and separates it hydrologically from the underlying Floridan aquifer. The unit grades laterally from a dense clay and sandy clay in the west to sandy clay, clayey sand and clayey limestone in the east. The average vertical hydraulic conductivity is estimated at about  $1 \times 10^{-5}$  ft/d in Okaloosa County and  $1 \times 10^{-3}$  ft/d in Walton County. The confining bed dips south-southwest at about 15 feet per mile and occurs at depths ranging from about 140 feet NGVD in northeastern Walton County to 125 feet below NGVD in southwestern Okaloosa County (Figure 6). The thickness of the confining bed ranges from 475 feet in southwestern Okaloosa County to less than 50 feet in southeastern Walton County (Figure 7). The unit restricts the movement of water between the sand-and-gravel and Floridan aquifer. It also restricts salt water from Choctawhatchee Bay and the Gulf of Mexico from moving downward into the Floridan aquifer. Its confining properties decrease to the east of the study area as indicated by decreasing thickness and increasing vertical hydraulic conductivity.

The upper limestone of the Floridan aquifer constitutes the principal aquifer in southern Okaloosa and Walton counties, supplying most of the water used in that area. Groundwater storage and movement takes place through a combination of small solution fissures and larger cavities and solution channels. The aquifer is confined or artesian throughout the study area. Water movement from the recharge area through southern Okaloosa and Walton counties is illustrated schematically on Figure 8. The large cone of depression

centered over the Fort Walton Beach area is a result of heavy water use. Predevelopment heads averaged about 30 feet above NGVD along the coastline.

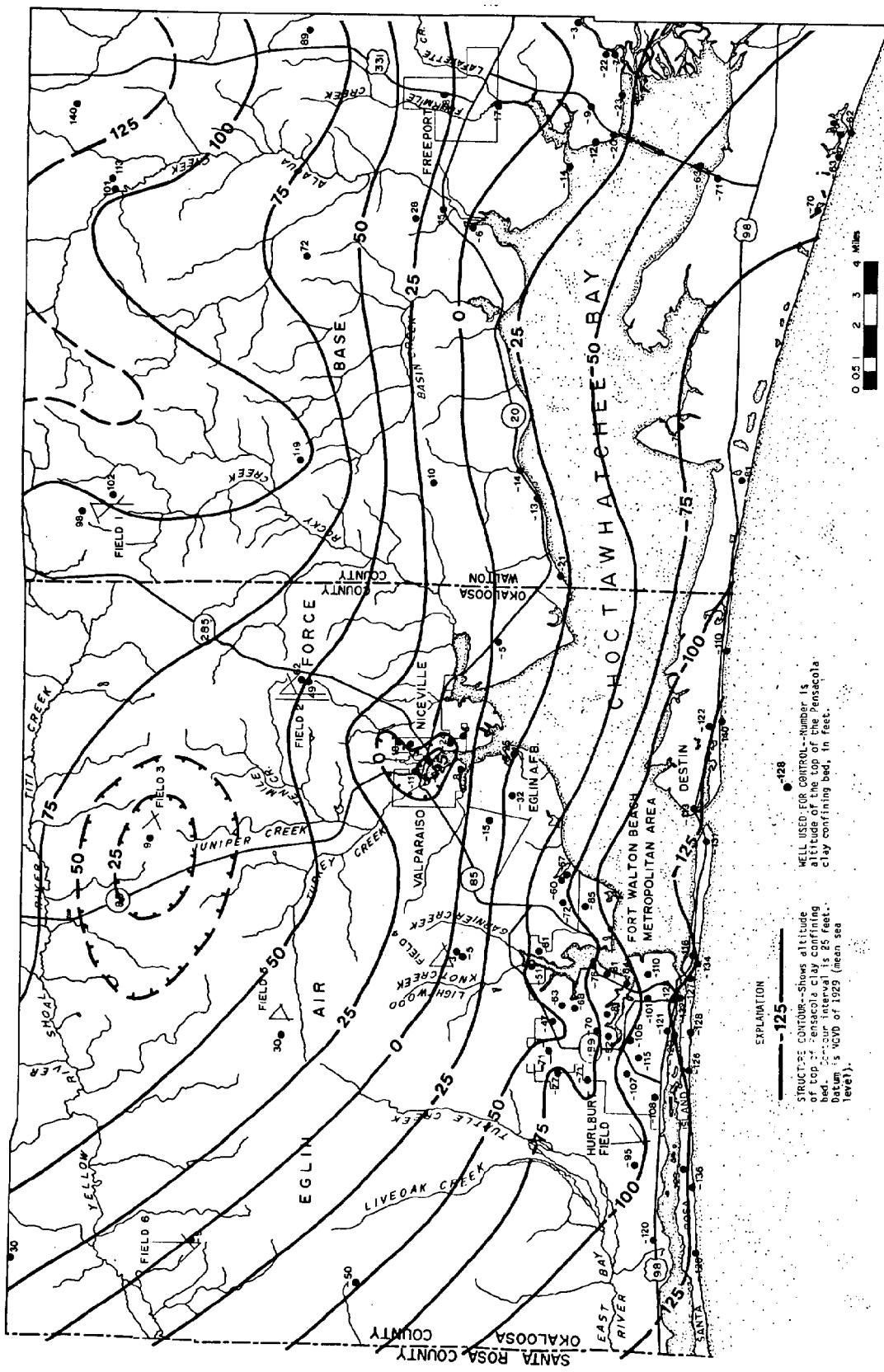


Figure 6. Map showing altitude of the top of the Pensacola clay confining bed

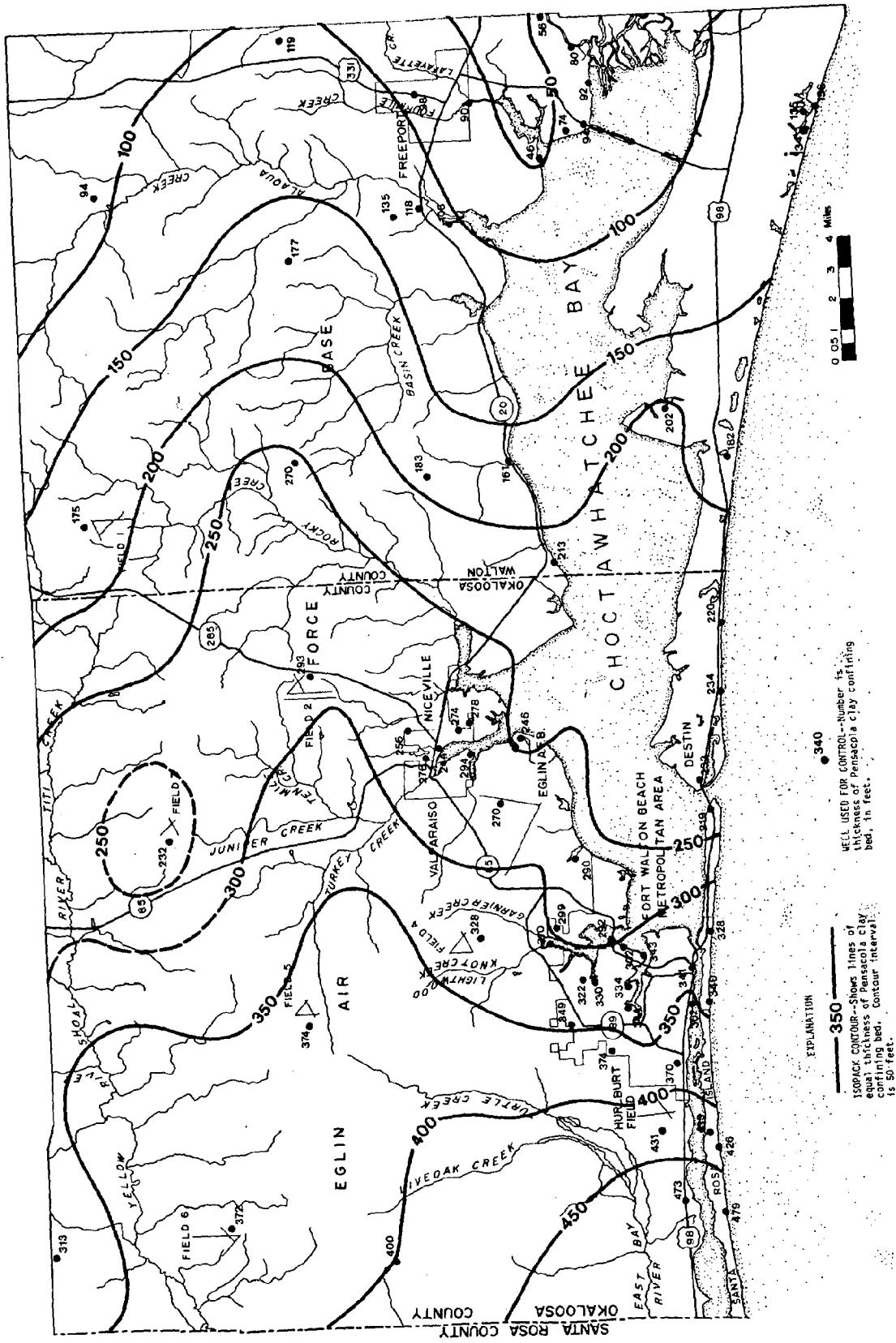


Figure 7. Map showing thickness of the Pensacola clay confining bed

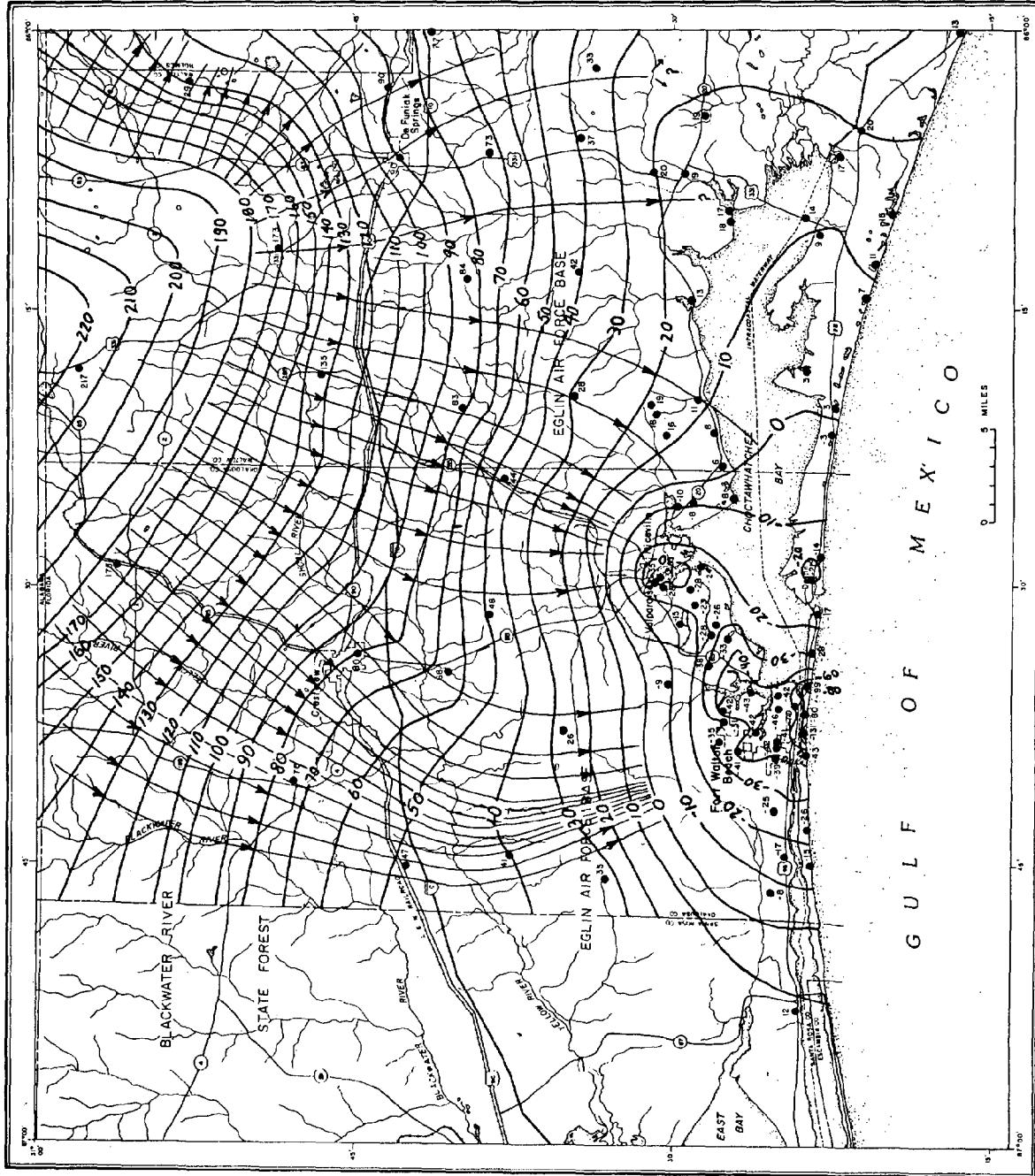


Figure 8. Map showing potentialometric surface of the upper limestone of the Floridan aquifer in March 1978 and the direction of ground water movement in Okaloosa and Walton counties and adjacent areas

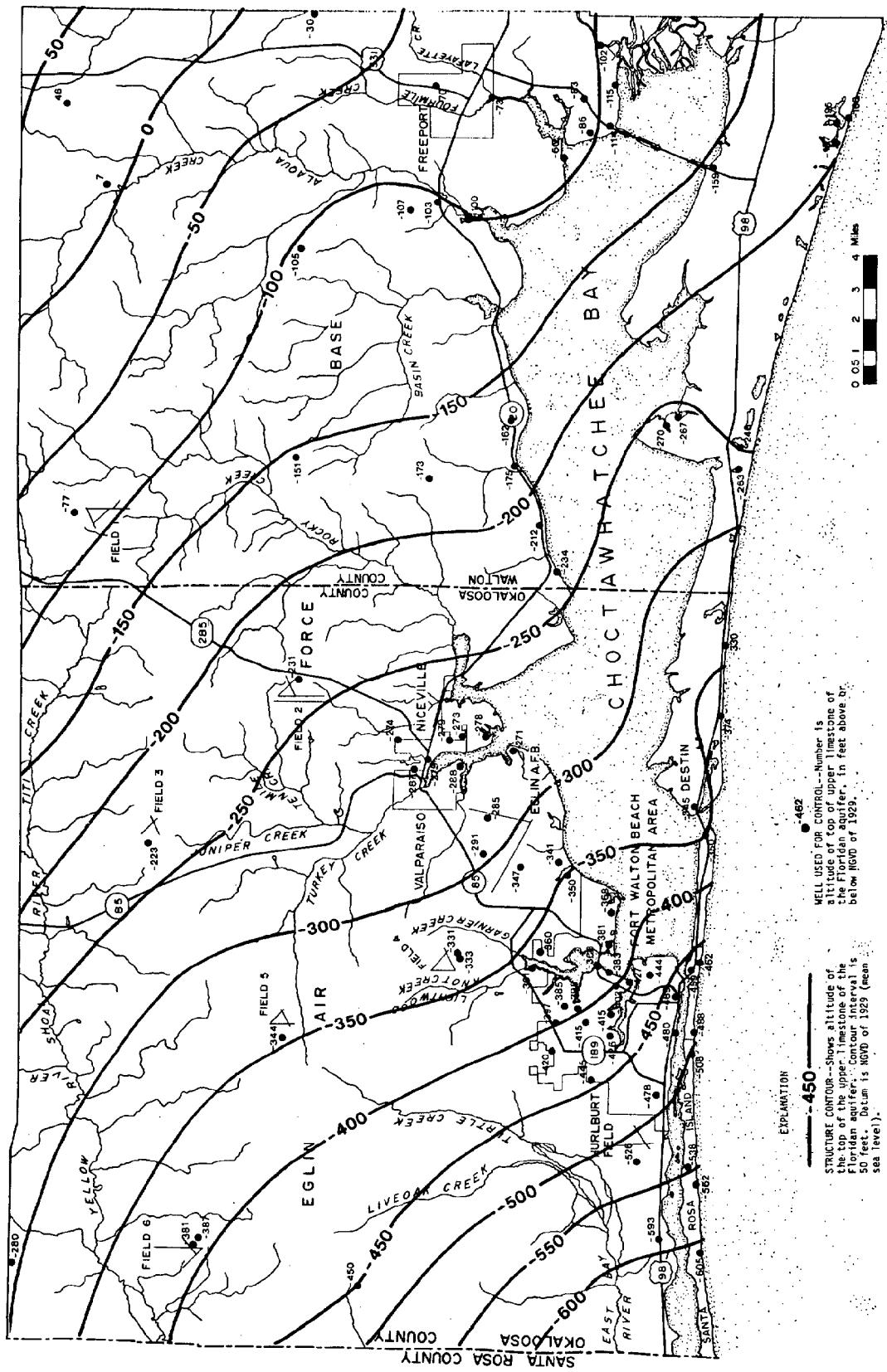


Figure 9. Map showing altitude of the top of the Floridan aquifer

The upper part of the Floridan aquifer ranges in thickness from about 200 feet in eastern Walton County to 400 feet in parts of coastal Okaloosa County. The top of the Floridan aquifer dips southwest at 15 to 20 feet per mile and ranges from about 50 feet above NGVD in northeastern Walton County to about 650 feet below NGVD in southwestern Okaloosa County (Figure 9). Aquifer tests indicate that no significant leakage occurs between the Floridan and sand-and-gravel over short pumping durations. The analyses also showed that the more permeable limestone sections occur near the base of the Floridan in the Fort Walton Beach area.

Utilizing a calibrated digital model of the Floridan aquifer, the calculated inflow to southern Okaloosa and Walton counties from upgradient areas was estimated to be 31.5 Mgal/d (48.8 cfs). Downward movement of water through the Pensacola clay confining bed contributes additional water to the Floridan aquifer within the region, wherever the head at the base of the sand-and-gravel stands higher than the potentiometric surface of the Floridan aquifer. In the Fort Walton Beach area, where the head gradient across the Pensacola clay is greatest, the volume of leakage averages approximately 2-3 Mgal/d based on the results of the model studies. The comparatively small amount of leakage is attributable to the thickness and low permeability of the Pensacola clay confining bed.

Complete water quality analyses, for monitor wells in the study area, indicate that there are significant lateral differences in the chemical characteristics of water in the upper limestone of

the Floridan aquifer. Water temperature generally varies between 68 and 77 degrees Fahrenheit, but is nearly constant in any individual well. Hardness, as calcium carbonate, is usually below 150 mg/l, the PH usually ranges between 7.5 and 8.5, and the chloride is normally less than 10 mg/l. In coastal areas, however, chloride concentrations usually range between 25 and 75 mg/l, except in more seriously degraded areas where chloride concentrations normally accompanies an increase in sodium within the study area. Figures 10 and 11 show, respectively, chloride and sodium concentrations in the upper limestone of the Floridan aquifer. High concentrations of chloride and sodium are evident in southeastern Walton County. Salinity in the aquifer increases with depth, indicating that the source of high chlorides is attributable to upward migration of saline water from depth. The potential for upward movement and discharge of upper Floridan aquifer water into Choctawhatchee Bay is greatest in this area as a result of both potentiometric heads greater than water levels in the Bay and reduced confining properties of the Pensacola clay confining bed. The confining unit decreases in thickness and becomes more permeable in the eastern portion of the Bay. The extent to which water is interchanged in the eastern end of the Bay is unknown. However, the contribution of water from the Floridan aquifer is expected to be minor compared to other sources.

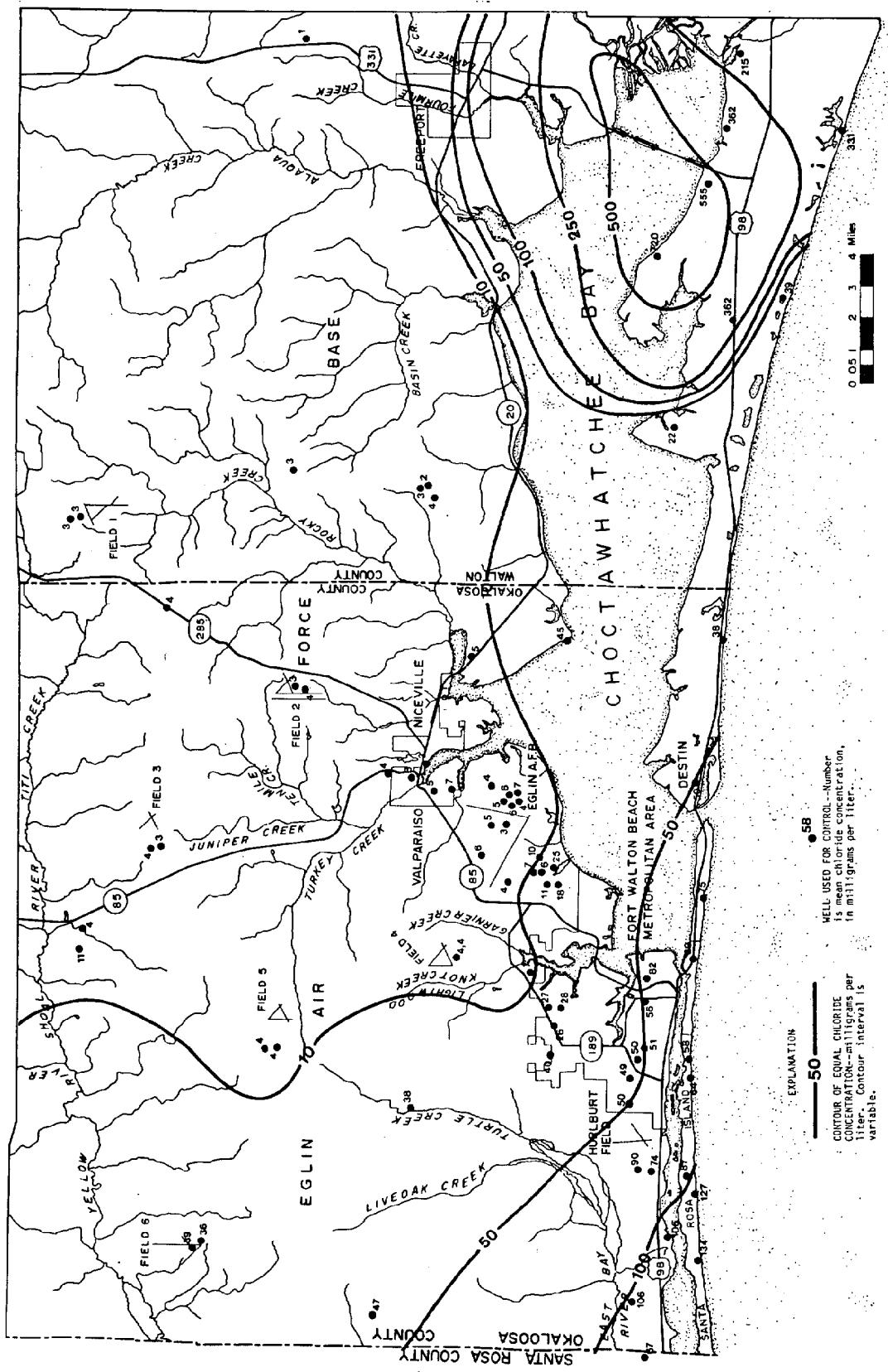


Figure 10. Map showing mean chloride concentrations in water from the upper limestone of the Floridan aquifer.

Figure 10. Map showing mean chloride concentrations in water from the upper limestone of the Floridan aquifer.

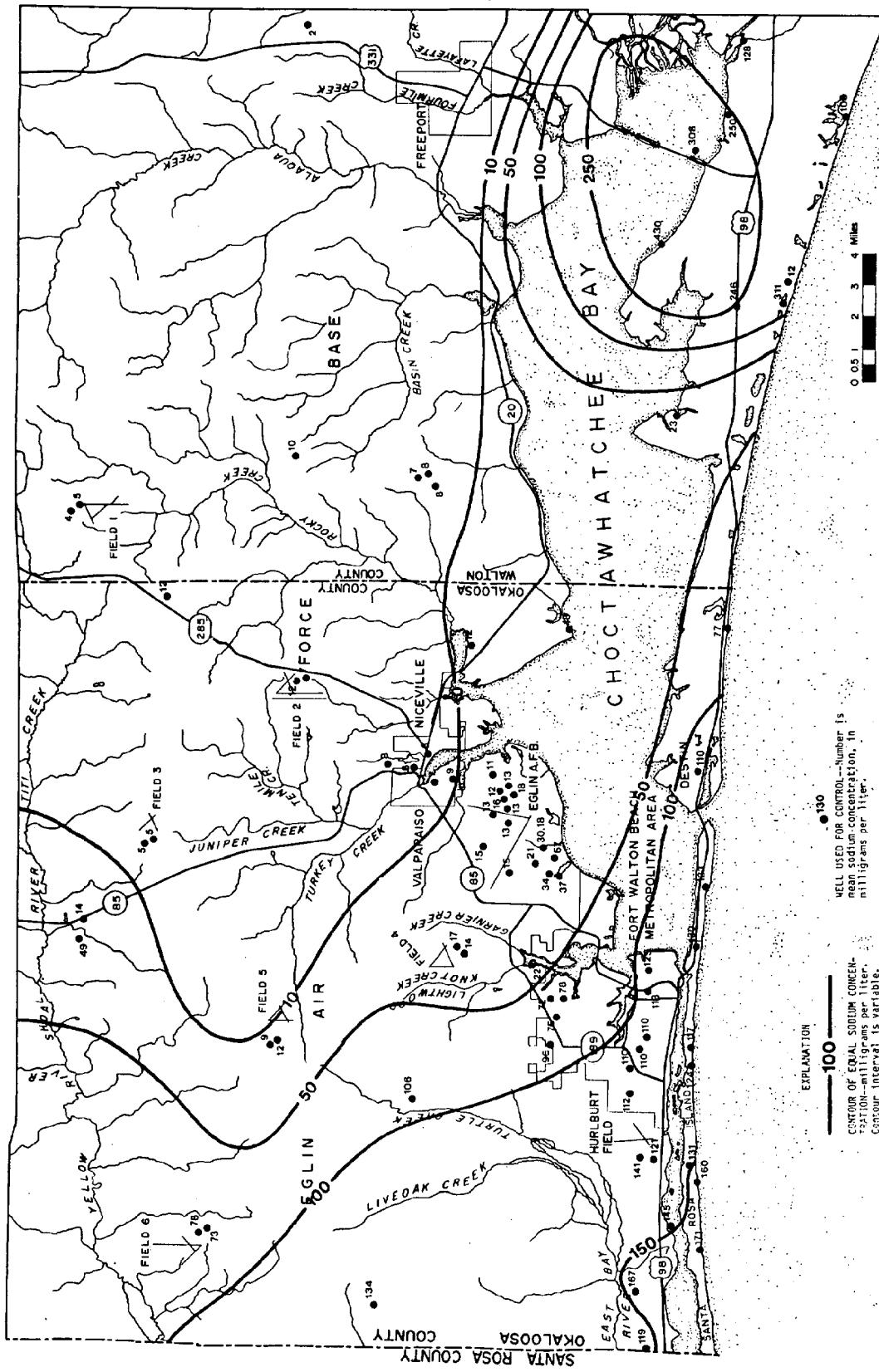


Figure 11. Map showing mean sodium concentrations in water from the upper limestone of the Floridan aquifer

## OCCURRENCE OF ANOMALOUS TEMPERATURES

The first occurrence of the high water temperatures was observed on March 10, 1982, during an intensive data collection effort conducted by the Northwest Florida Water Management District in cooperation with the U.S. Geological Survey (USGS). Data gathered during that study included water levels at six stations and water velocity, salinity, temperature, and conductivity at three depths per station at 19 stations. Figure 12 shows the locations of the monitoring sites. Observations were made continuously over a 24 hour period beginning on March 9, 1982, at 5:00 p.m. and ending the next day at 4:00 p.m. Four boats with two-person crews comprised of USGS personnel with NFWFMD personnel serving as backup and relief crews comprised the primary data acquisition effort. One District boat and crew served as backup and supply boat. All effort was coordinated by USGS and District personnel via radio from Stake Point. Temperature readings were obtained using YSI Model 33MSCT meters, manufactured by Yellow Springs Instrument Co., Inc.

Water temperatures were observed to begin rising at 4:00 a.m. on March 10, 1982, and continued to rise over the following 12 hours until 4:00 p.m. when the data acquisition operation was terminated. Immediately following termination of the data acquisition phase (after 24 hours of continuous effort), all meters were calibrated and checked with salinity standards and mercury thermometers. All

equipment was confirmed to be operating normally. Temperatures in the western half of the Bay rose from a background of 60°F, reaching a maximum of 109°F at two stations. This anomaly occurred at eight of the 19 stations monitored and was recorded by two crews using different sets of instruments. The phenomenon is documented graphically in Figure 13, which shows changes in temperature with time and depth at all the stations affected. The tide and flow conditions are also given for reference. Figures 14 and 15 show the areal distribution of temperatures in bottom waters at 8:00 a.m. and 4:00 p.m., respectively. For a more detailed account of the occurrence, Tables 1 and 2 in Appendix A contain temperature, conductivity, and time data for all the stations affected. Appendix B, Tables 1 and 2 show summaries of physical characteristics of data taken at Fourmile Point.

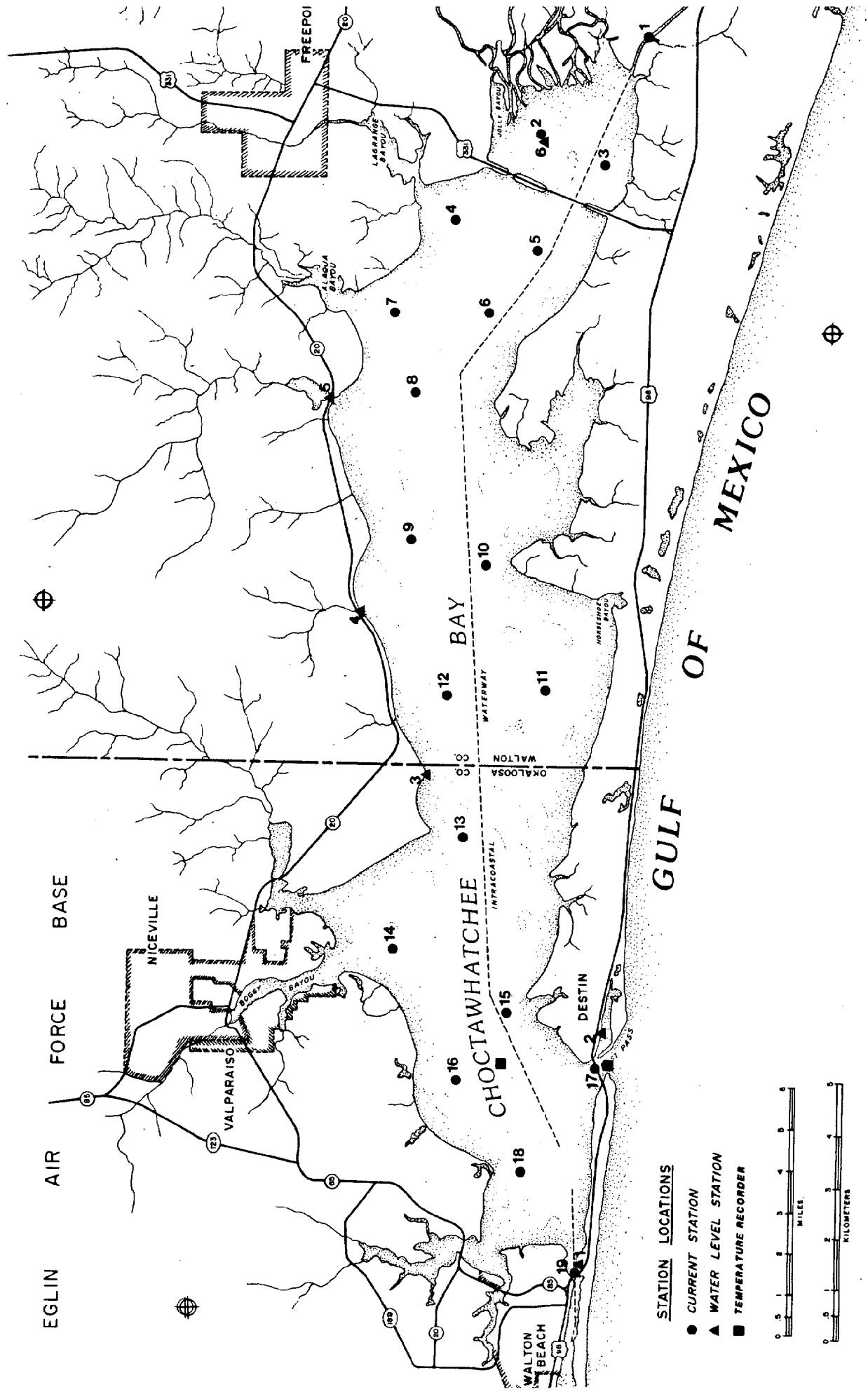


FIGURE 12. LOCATION OF MONITORING STATIONS

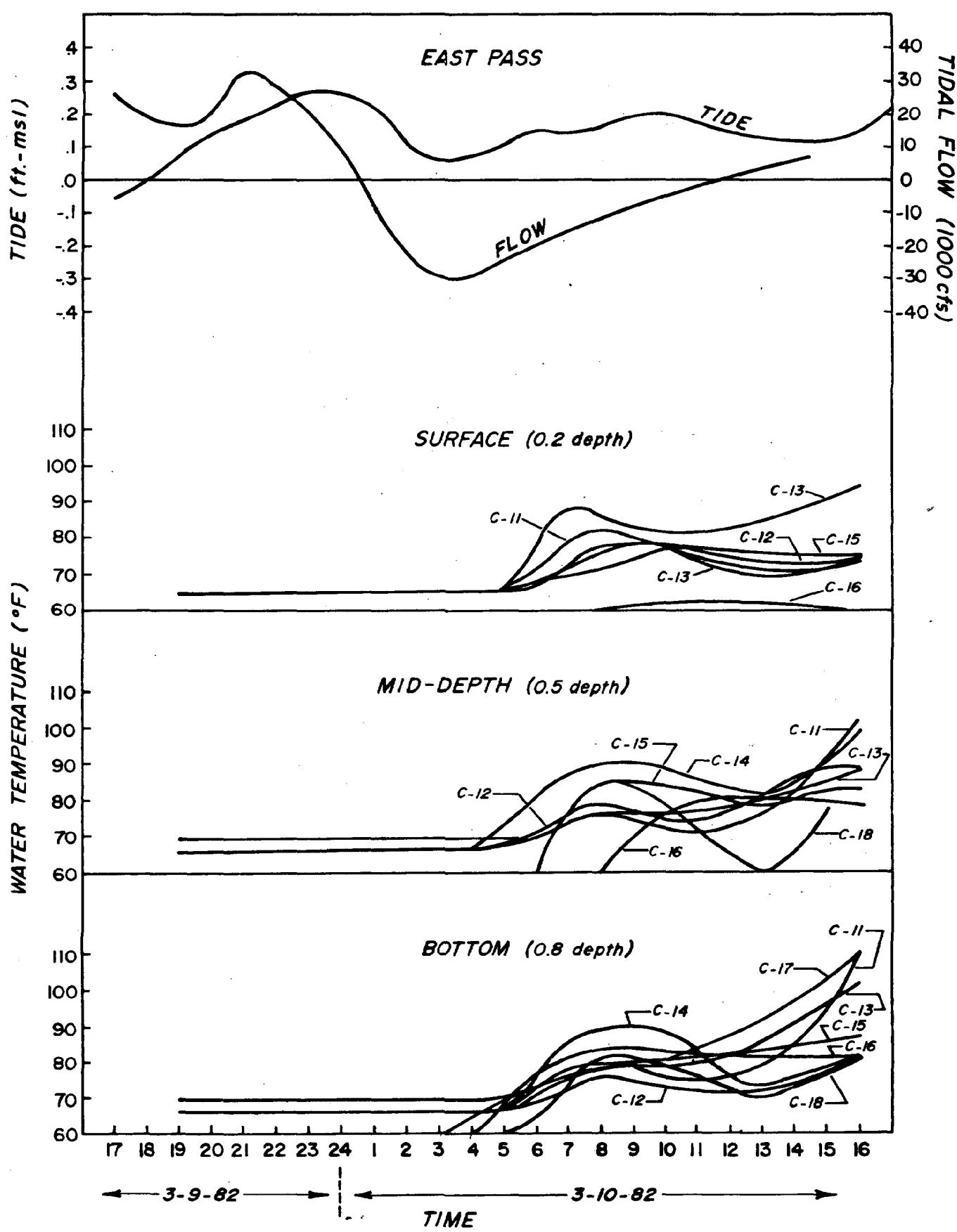
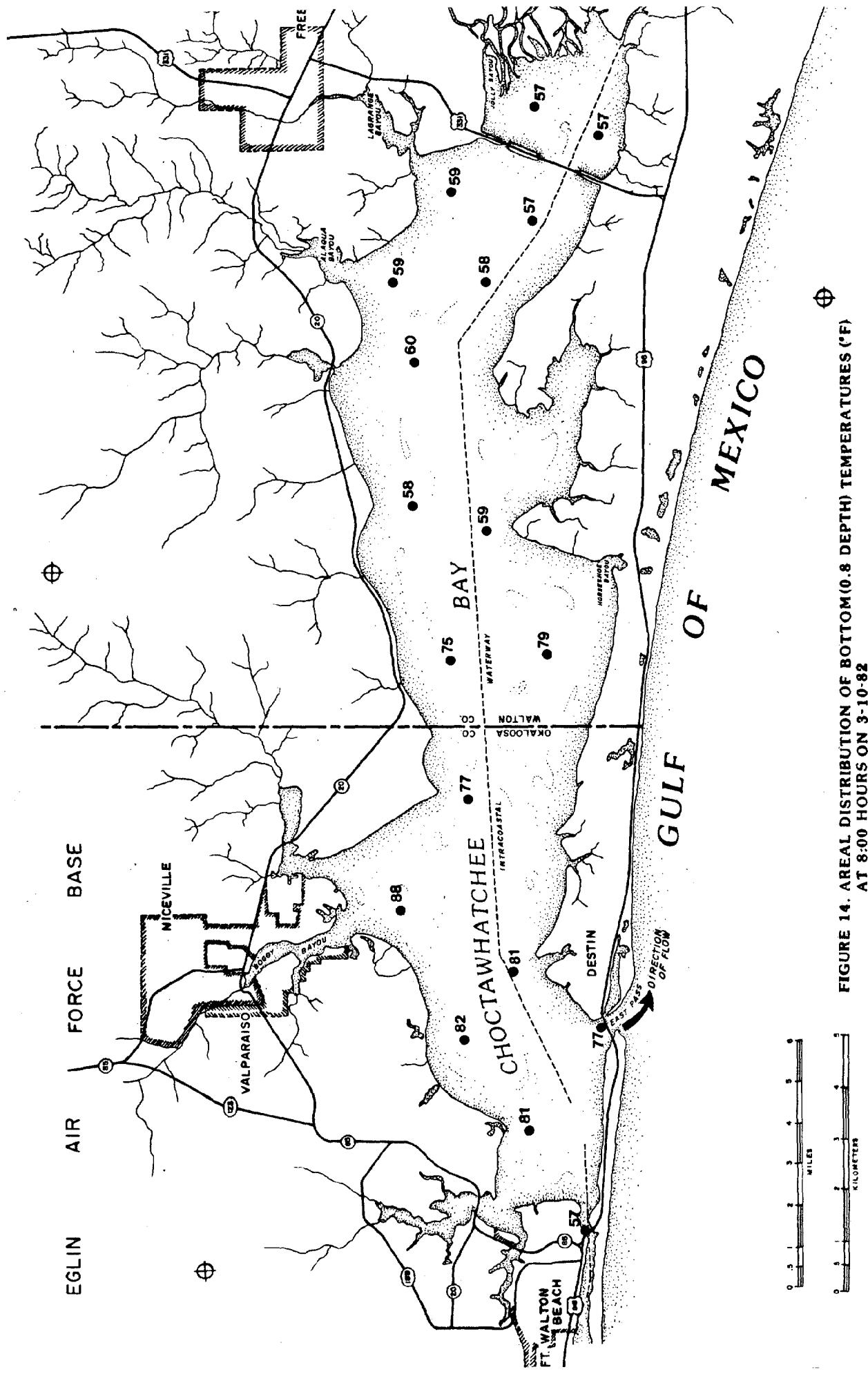
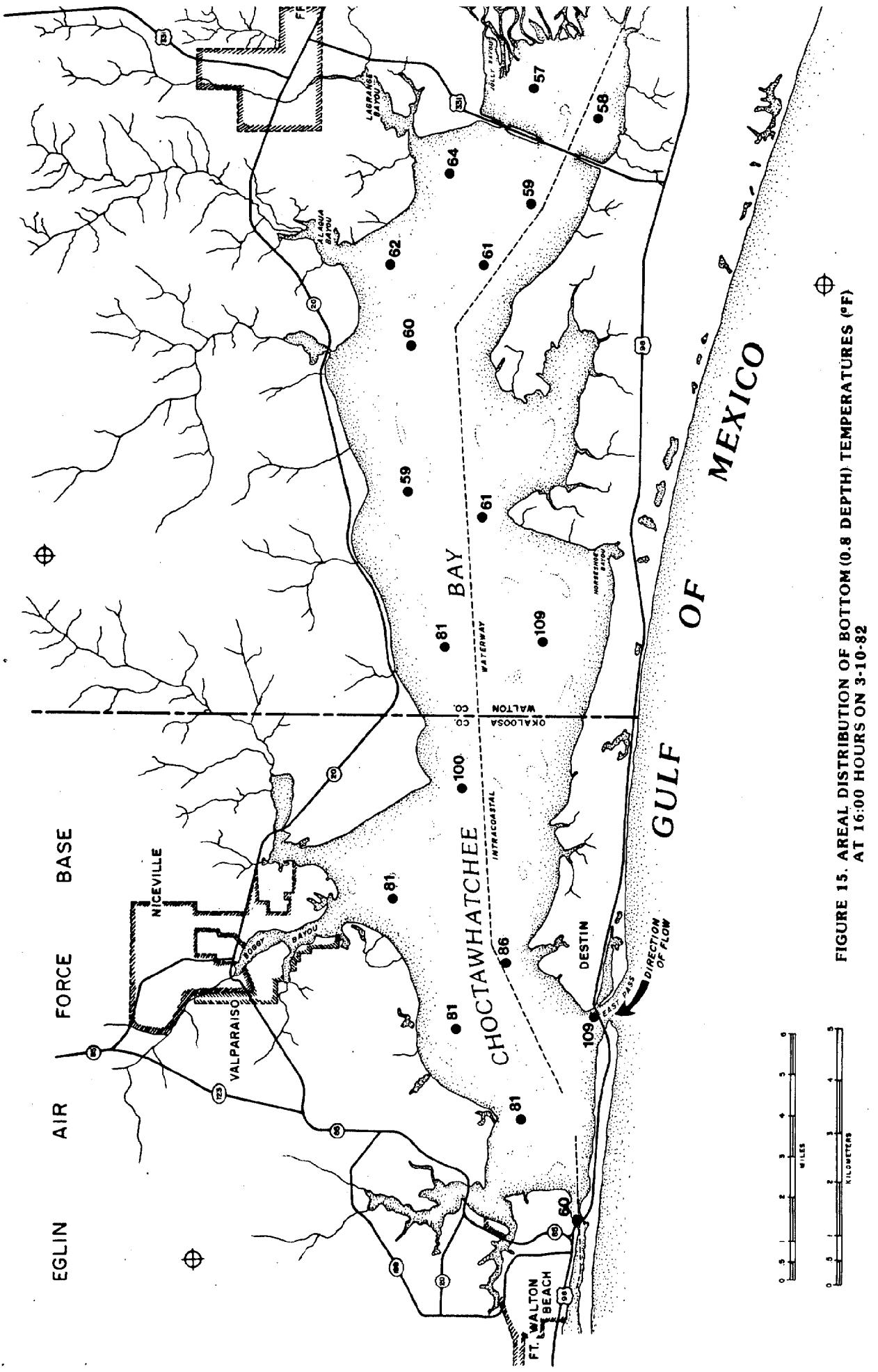


FIGURE 13. GRAPHICAL REPRESENTATION OF TEMPERATURE ANOMALY





The following observations may be made from examining Figures 13-15:

--The rise in water temperature began at about 4:00 a.m. when the tide was at its lowest level and water at East Pass was flowing out of the Bay at peak flow.

--The anomaly was restricted to stations 11 through 18 in the western half of the Bay (which is also the deepest portion of the Bay).

--Bottom waters were affected the most as they show the broadest extent and highest temperature change.

--Temperatures rose concurrently at most of the stations. The maximum time difference observed was on the order of two hours.

--The eastern half of the Bay did not experience any unusual temperature changes as the temperatures remained relatively constant at about 60°F. Since the Choctawhatchee River discharges into the eastern end of the Bay, it is apparent that the river is not associated with the anomaly.

--The Santa Rosa Sound tidal flows also do not appear to be the source of the high temperatures as values remained around 60°F throughout the 24-hour period.

A second occurrence of the anomalous temperatures was recorded by District personnel on March 24 and 25, 1982, while collecting flow data at the Santa Rosa Sound/Highway 98 bridge. Sporadic trips to the East Pass were made in order to conduct temperature and salinity profiles under the Highway 98 bridge. Table 1 contains a summary of the observations.

Table 1.--Temperature and Salinity Profiles at the East Pass

Direction of Flow	OUT	IN	IN	OUT	OUT	IN*
Date	3-24-82	3-24-82	3-24-82	3-25-82	3-25-82	3-24-82
Time	5:40PM	7:30PM	10:20PM	3:50AM	6:00AM	9:00AM
<hr/>						
Depth (ft)	Temperature ( $^{\circ}$ F)/Salinity (ppt)					
3	73/9	72/30	75/36	75/8	75/7	77/11
6	73/9	86/30	89/36	75/8	104/7	86/11
9	77/11	86/30	89/37	90/8	100/7	93/11
12	79/20	84/30	88/37	87/9	100/8	93/12
15	79/21	86/30	88/37	86/9	95/9	113/23
18	82/28	86/30	86/37	86/11	95/13	113/28
21	86/28	90/30	84/37	86/16	104/14	122/31
24	86/28	90/30	84/37	90/19	109/16	>122/31
27	86/28	90/30	84/37	90/20	113/18	>122/32
30	86/28	90/30	84/37	90/21	113/19	>122/32
33				93/22	113/19	>122/32
36				95/22	113/19	>122/32

\*Flowing into the Bay at low velocity. It appeared as if the flow direction had just reversed.

Two conclusions that may be drawn from examining these data:

--There is a tendency for temperatures to increase with depth. Also, since salinity increases with depth, the more saline waters experienced the highest temperatures.

--Overall, temperatures tend to decrease towards the end of the inflow cycle and to increase towards the end of the outflow cycle. This would seem to suggest that the high temperatures originated from within the Bay and not from the Gulf of Mexico. This is also apparent from examination of Figure 13 which shows that temperatures began to rise during the outflow cycle.

## HEAT BUDGET

The purpose of this section is to estimate the magnitude of heat required to raise the temperature of the Bay waters to the levels which were observed. This will give an indication of energy requirements and possibly shed some light on the question of whether the phenomenon originated from natural or man-made sources.

All calculations were based on the data collected on March 10, 1982, when the anomalies were first observed. The Bay was divided into sections encompassing the center of influence of each station as shown in Figure 16. In turn, each section was divided into three levels corresponding to the three depths at which data were recorded. The heat capacity equation was then used to calculate the amount of heat present in each level given the temperature, salinity, and volume of water involved. Specific heat values at constant pressure were obtained from Cox and Smith (1959) for the ranges of salinity and temperature observed.

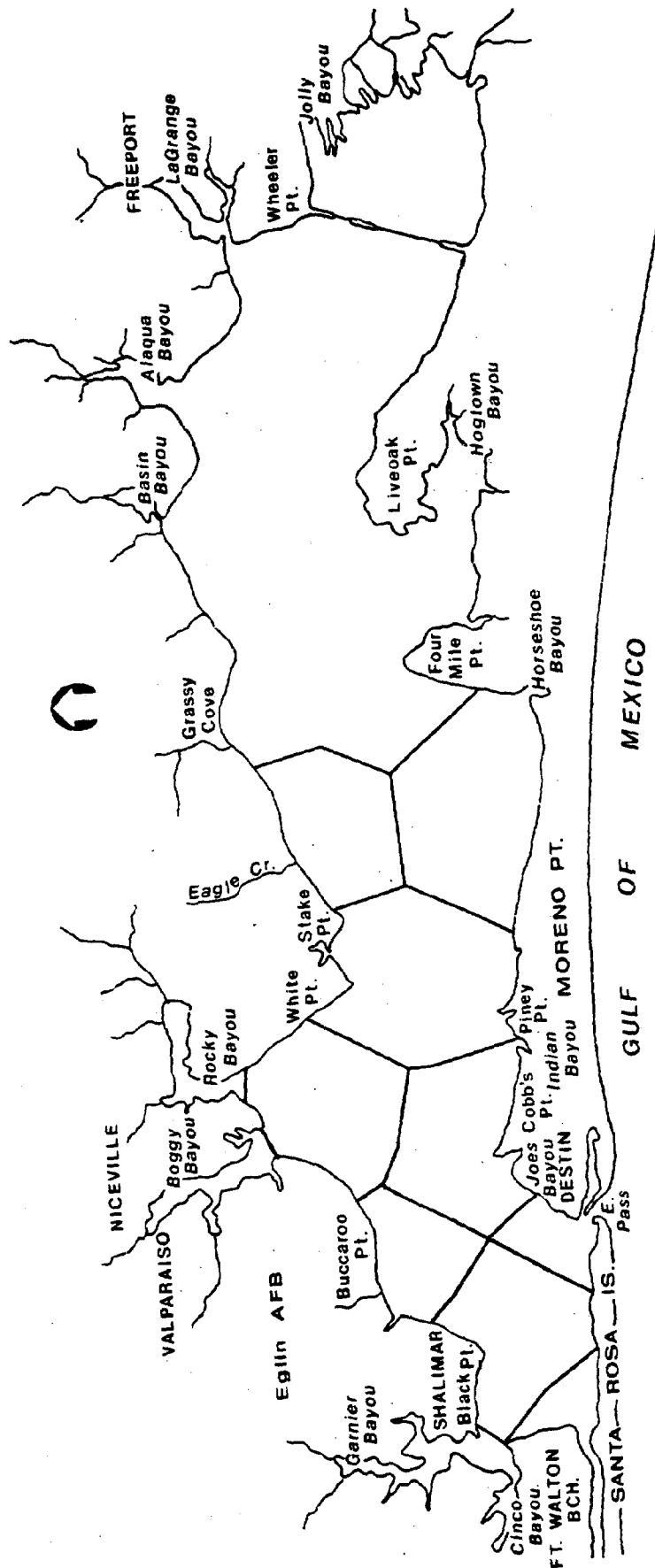


Figure 16. Sections used in calculating Heat Budgets.

The form of the heat capacity equation used is:

$$E = FV\rho C_p(T_2 - T_1)$$

Where  $E$  = energy expended in raising water temperature from  $T_1$  to  $T_2$  (billion kilowatt-hours)

$\rho$  = density of water ( $\text{gms/cm}^3$ )

$C_p$  = specific heat of water at given temperature and salinity (calories/ $\text{gm}^{-\circ}\text{C}$ )

$T_1, T_2$  = temperature (degree Celsius)

$F$  = unit conversion factor ( $1.163 \times 10^{-15}$  billion kilowatt-hours/calorie)

$V$  = volume of water ( $\text{cm}^3$ )

Heat amounts were estimated at three different times. Namely, at 4:00 a.m. (immediately before temperatures began rising), 8:00 a.m., and 4:00 p.m. (the end of the monitoring period). Finally, the heat values at 4:00 a.m. were subtracted from those at 8:00 a.m. and 4:00 p.m. In order to obtain the heat gain, respectively, over a 4-hour and 12-hour period. The resulting values were 9.2 and 12.4 billion kilowatt-hours of energy generated over four and 12 hours, respectively. Accordingly, about 74 percent of the total energy produced was generated during the first four hours of the event.

The numbers given above are so large that it seems improbable for that energy to have originated from man-made sources. This is clearly apparent when one considers that the amount of thermoelectric energy generated in the state of Florida in the year 1980 totaled 129.4 billion kilowatt-hours (Leach, 1983). Thus, the total energy associated with the anomaly is equivalent to over one month of thermoelectric energy consumption in the entire state.

It should be pointed out that the numbers given herein are only approximations, since the data used in their development is relatively sparse. Data from only eight stations were applied over a total surface area on the order of 60 square miles. Nonetheless, the numbers suggest that the phenomenon may have been a natural occurrence. Even if the volume of water used in the calculations were ten times too large, the resulting values would still be large enough to practically eliminate the possibility of a man-made source.

## WATER BUDGET

A water budget consists of a balance of water volumes within a given area. The balance is based on the hydrologic equation which states that, water inflow minus outflow is equal to the change in storage over a given period of time. In the case of Choctawhatchee Bay, changes in storage over time may be calculated on the basis of all known inflow/outflow points. Changes in storage may be expressed as water level fluctuations and compared against observed water level data. If observed and calculated levels compare favorably, it may be concluded that all inflow/outflow points feeding the Bay were monitored. Otherwise, significant differences may indicate the presence of an unknown source.

The water budget was developed on the basis of the data collected on March 10, 1982, when the anomaly was first observed. The data used in the water balance calculations included hourly flow values at East Pass, Santa Rosa Sound, Intracoastal Waterway, Choctawhatchee River, and other streams which discharge into the Bay. The individual flows from each of the flow points were accumulated to arrive at the new hourly flow into or out of the Bay. In turn, the new hourly flows were converted into water levels by spreading the hourly changes in volume over the surface area of the Bay (120 square miles). The calculated water levels were compared to the observed water levels in order to detect any significant errors.

The water budget calculations and results are given in Tables 2A and 2B. Positive flows indicate water flow into the Bay and the positive differences between observed and calculated levels represent higher observed than calculated values.

An examination of the water level differences reveals that the largest difference is in the order of 0.07 ft. Since the observed values were obtained by averaging the high and low readings produced by wave action on the staff gage, this value is within the expected range of measurement error. Other errors may arise as a result of streamflow measurement errors and the time lag between the flows and the tides. In summary, the differences between observed and calculated water levels is not significant and, consequently, it may be concluded that all of the Bay's flow points were included in the data collection.

Table 2A.--Water Budget

FLOW, cubic feet per second

Date/ Time	East Pass	Santa Rosa Sound	Intra- coastal Waterway	River	Total
<hr/>					
<u>3-9-82</u>					
6:00PM	20,000	1,000	120	9,550	30,670
7:00PM	16,000	3,000	560	9,550	29,110
8:00PM	22,000	4,000	1,000	9,550	36,550
9:00PM	34,000	3,600	1,400	9,550	48,550
10:00PM	32,000	3,500	1,500	9,550	46,550
11:00PM	20,000	3,600	1,360	9,550	34,510
<hr/>					
<u>3-10-82</u>					
12:00AM	10,000	4,800	1,200	9,550	25,550
1:00AM	- 2,000	5,200	1,280	9,550	14,030
2:00AM	-16,000	6,000	2,000	9,550	1,550
3:00AM	-26,000	8,000	1,880	9,550	- 6,570
4:00AM	-34,000	9,800	880	9,550	-13,770
5:00AM	-25,000	5,000	0	9,550	-10,450
6:00AM	-21,000	- 3,500	-1,200	9,550	-16,150
7:00AM	-16,000	- 7,000	-1,500	9,550	-14,950
8:00AM	-12,000	- 9,600	-1,500	9,550	-13,550
9:00AM	- 7,000	-10,400	-1,200	9,550	- 9,050
10:00AM	- 3,000	-10,600	- 880	9,550	- 4,930
11:00AM	200	- 9,100	- 680	9,550	- 30
12:00PM	2,300	- 8,100	- 580	9,550	3,170
1:00PM	8,300	- 7,000	- 450	9,550	10,400
2:00PM	12,500	- 5,400	- 300	9,550	16,350

Table 2B.--Water Budget

WATER SURFACE ELEVATION  
(Referenced to NGVD)

Elevation (ft)			
Date/ Time	Calculated	Observed	Difference
<u>3-9-82</u>			
6:00PM	-.16	-.16	.0
7:00PM	-.129	-.12	.009
8:00PM	-.089	-.08	.009
9:00PM	-.037	-.05	-.013
10:00PM	-.013	.0	.013
11:00PM	.05	.04	-.01
<u>3-10-82</u>			
12:00AM	.078	.09	.012
1:00AM	.093	.14	.047
2:00AM	.094	.17	.076
3:00AM	.087	.16	.073
4:00AM	.072	.13	.058
5:00AM	.061	.10	.039
6:00AM	.044	.09	.046
7:00AM	.028	.08	.052
8:00AM	.013	.07	.057
9:00AM	.003	.06	.057
10:00AM	-.002	.05	.052
11:00AM	-.002	.06	.062
12:00PM	.001	.07	.069
1:00PM	.013	.08	.067
2:00PM	.03	.10	.07

## DEVELOPMENT OF STUDY ASPECTS

Because the high temperatures were observed during the course of data acquisition in another project, it was felt that this phenomenon, if it occurred again, should be properly documented since it could exert an important influence on the Bay. One of the first difficulties encountered was to design a study regimen that would have the greatest chance of recording these changes. In order to properly design a study scheme, several potential causes for the temperature anomaly had to be considered. The most likely being that old oil test wells in the area had corroded their casings and were leaking hot saltwater into the local aquifer. The indication that a high geothermal gradient is present in the area is documented by Smith and Fuller (1977), and by previous District investigations of deep wells in the area. The use of old free-flowing artesian oil test wells to develop commercial spas was at one time a fairly common practice in Florida and many spas were developed in this manner. One such well was drilled near the Brooks Bridge on Okaloosa Island. It did not yield the needed flows and remains unused in the parking lot of a local business in Fort Walton Beach. This well, known locally as the "Docie Bass" well, was drilled in 1960 to a depth of 5,400 feet and had an artesian head of 23 feet above msl with a reported temperature of 132°F (Milner, 1984). Pertinent data on this well is included in Table 3. Note that the temperature is low because the well is not presently flowing and the temperature represents the

temperature in the upper casing. Another deep well (W-3365) was located at Fourmile Point, 2.5 miles east of Sampling Site 11. It was drilled in 1954 to a depth of 6,010 feet, a depth at which the temperature should be approximately 146°F. A third well was drilled at Destin in 1954 to a depth of 6,250 feet. Pertinent data is lacking on this well. The latter wells have reportedly been abandoned by setting several cement plugs in the casing and cutting the casing about four feet below land surface (a common practice in the oil industry). These two wells could not be located during this study.

The existence of a known high thermal gradient in the area and the presence of old oil test holes suggested a possible relationship with the observed anomalous high temperatures observed in Choctawhatchee Bay. Other possibilities, however remote, were considered. These included the possible presence of an unknown geologic fault, possible thermal submarine springs, a chemical discharge of unknown origin and even activities from local military installations. All logical conclusions seemed to implicate the old oil test wells. The exact mechanism for such a large transfer of heated water was not determined, but the study was designed based on their assumed role in the problem. Additionally, a possible relationship between the discharge from the wells and extremes in the tidal system was part of the consideration since the anomalies were observed during the spring equinox, when the mean tide reaches the lowest level of its annual cycle. Data from a deep monitor in the Bay was to document the temperature in the Bay during the autumnal

equinox. Data obtained from East Pass would document any high temperature water leaving or entering the Bay. Both the bridge and the deep sensor were to be discontinued in the Fall of 1983.

Table 3.--Water-quality analyses of water from Docie Bass deep well and from Choctawhatchee Bay

[Concentrations in milligrams per liter (mg/L) except as noted]  
(Data from U.S.G.S.)

Docie Bass Well at Fort Walton Beach  
Station ID: 302355086355401  
Lat 30°23'55", Long 86°35'54"  
Collection date: March 30, 1982  
Time: 1540  
Depth of sample: at land surface (a flowing well)

Choctawhatchee Bay near Stake Point  
Station ID: 302558086255600  
Lat 30°25'58", Long 86°25'56"  
Collection date: March 31, 1982  
Time: 1700  
Depth of sample: 22 ft.

Water-quality parameter	Value	Water-quality parameter	Value
Alkalinity, total $\text{CaCO}_3$	55	Alkalinity, total $\text{CaCO}_3$	100
calcium, dissolved	5,600	calcium, dissolved	380
chloride, dissolved	66,000	chloride, dissolved	17,000
fluoride, dissolved	0.1	depth, loc vert (feet)	27.0
hardness	18,000	fluoride, dissolved	0.5
hardness N. Carb L-EP	18,000	hardness	5,500
magnesium, dissolved	900	hardness N. Carb L-EP	5,400
pH, laboratory (units)	8.0	magnesium, dissolved	1,100
pH, field (units)	7.7	pH, laboratory (units)	7.6
potassium, dissolved	230	potassium, dissolved	320
residue, dissolved	110,000	residue, dissolved	29,600
calculated sum		calculated sum	
residue on evaporation,	114,000	residue on evaporation	31,500
dissolved, at 180°C		dissolved, at 180°C	
silica, dissolved	11	silica, dissolved	0.5
sodium, absorption ratio	121	sodium, absorption ratio	49
sodium, dissolved	37,000	sodium, dissolved	83.0
sodium (percent)	82	sodium (percent)	75
specific conductance (lab)	146,000	specific conductance,	36,000
strontium, dissolved	170,000	field (umhos)	
(ug/L)		specific conductance,	
sulfate, dissolved	460	laboratory (umhos)	
water temperature (°C)	24.0	strontium, dissolved	37,000
		(ug/L)	
		sulfate, dissolved	2,400
		water temperature (°C)	17.0

## DATA ACQUISITION

In order to document the occurrence of the high temperatures, two continuous recorders were installed in Choctawhatchee Bay as part of this investigation. Their locations are shown in Figure 17. One recorder was installed at East Pass on the Bridge at Destin. This recorder, a U.S.G.S. Mini Monitor, is composed of a battery-operated electronics package, a Leopold Stevens Digital Input and Output 16-channel paper tape recorder, probes and extention cables with underwater connectors. The unit turns itself on every recording interval, scans, and records the parameters on the paper tape and then turns itself off until the next time to record. The recording interval is controlled by an internal crystal clock and is user-settable from 1-79 minutes. The electronics unit is housed in a water-tight canister 10" high by 10 1/2" diameter. Four probes were installed; a conductance and temperature probe at 16 feet and 30 feet below the surface. The total water depth was 36 feet.

The Mini Monitor system was located on a catwalk on the north side of the north bridge spanning East Pass and housed in an aluminum shelter about eight feet above the water surface. A four-inch diameter section of PVC pipe was attached to the bottom of the shelter and extended to four feet below the water surface. The pipe provided a protective conduit for the cables and anchor line where they were susceptible to damage by boats. The anchor line was a

length of parachute cord attached to the shelter floor and extended to a concrete weight on the bottom of the Bay directly below the shelter. The cables were run down the line and attached loosely with plastic ties about every six feet. This ensured that the cables would not "wave" about with changes in current speed and direction, yet facilitated their removal for cleaning or replacement. Data obtained from this monitor was from April 20, 1982, to October 5, 1983.

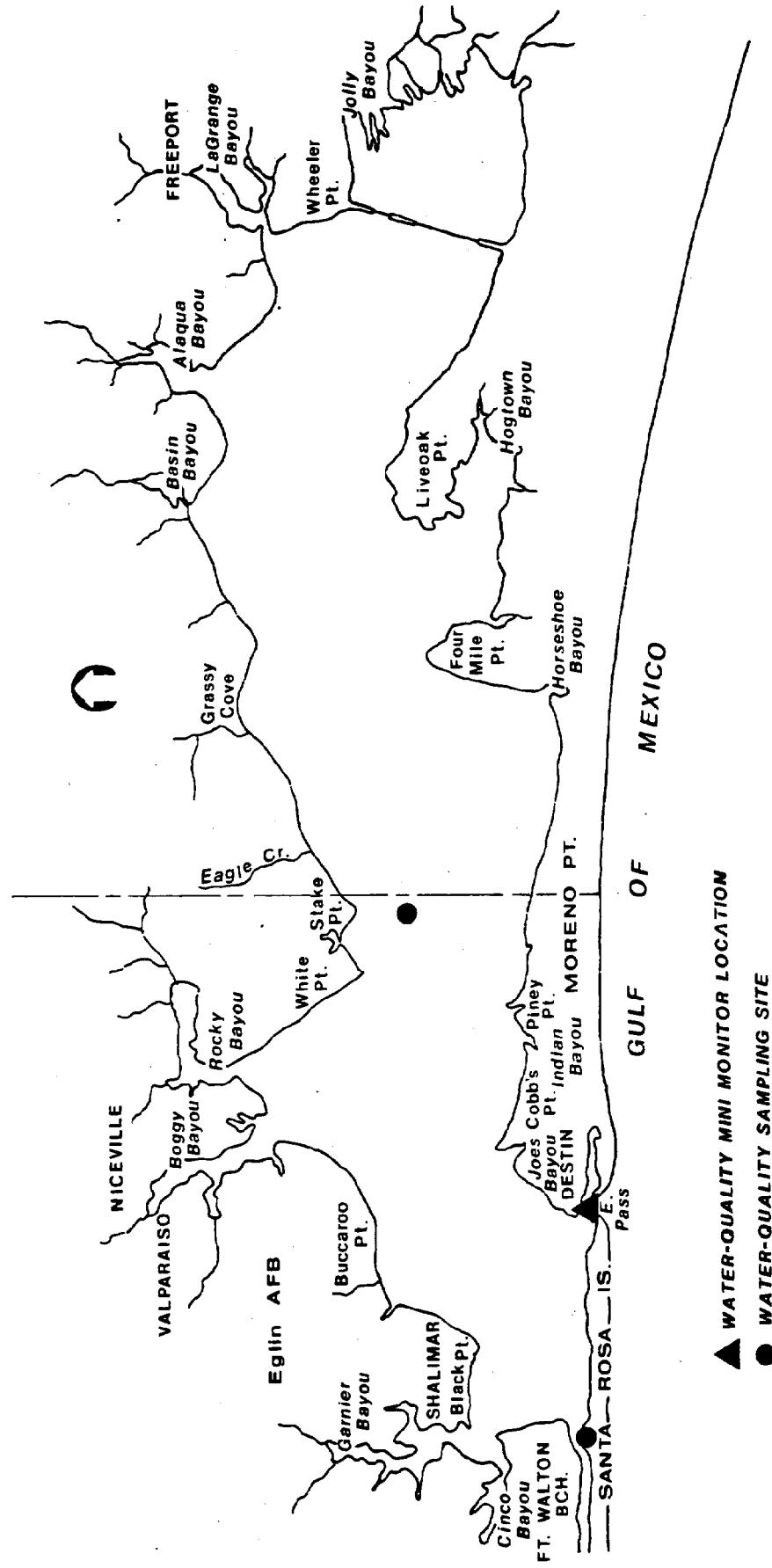


Figure 17. Locations of water-quality sampling, April 5, 1982.

On March 8, 1983, a submerged recording device known as a "Data Logger" (Figure 18) was placed on station between Piney Point and Fourmile Point. The logger was placed in 25 feet of water and, along with chain, cables and floats, extends from the bottom to within seven feet of the water surface. A surface float was anchored in the vicinity. Commercial fishermen and other boat operators utilizing nets or other subsurface equipment were requested to not pass closer than 300 yards of the logger. Total weight of the installation was in excess of 500 pounds. The location of this device was: latitude  $30^{\circ}25'35''$ , longitude  $86^{\circ}23'26''$ ; 0.5 nautical miles south of the Intracoastal Waterway; 0.6 nautical miles northeast of Danger Area 204.130 on NOAA nautical chart 11385, West Bay to Santa Rosa Sound; and 0.05 nautical miles north of a line between channel markers "51" and "49".

Record from the data logger was complete for the periods March 19 to May 10, and July 13 to October 4, 1983. During the interim period, May 11 to July 12, the logger was not on station but at a shrimper's house after he accidentally recovered it with his nets. The reliability of the logger was proven when, after being banged around and transported back to Florida State University, and after being out of the water for about two months, it was still recording data every 3.75 minutes when opened. Based on calibration tests after recovery, water temperatures are considered to be accurate to within  $0.18^{\circ}\text{C}$ , velocities within 0.407 centimeters per second (0.02 feet per second, and compass directions within  $1^{\circ}$ .

Data from both the Mini Monitor at the East Pass and from the submerged Data Logger are presented in Appendix B and as Table 4. It is apparent that no temperature anomalies were recorded by either instrument during the monitoring period.

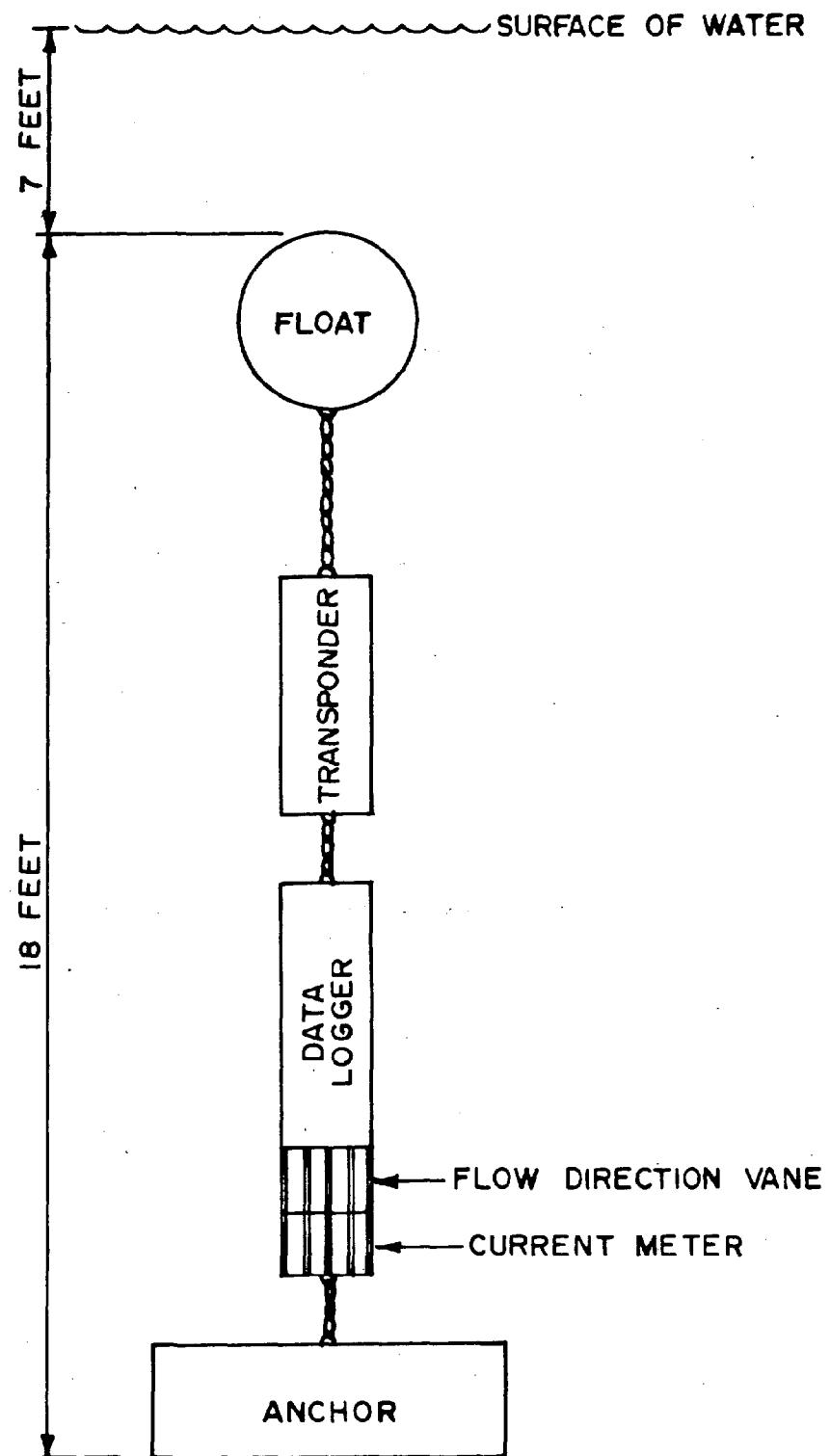


Figure 18. Major components of data logger deployed near Fourmile Point in Choctawhatchee Bay, Florida.

Table 4.--Current direction, velocity, and water temperatures near Fourmile Point in Choctawhatchee Bay, Florida

Date	Average velocity (cm/s)	Maximum velocity (cm/s)	Minimum velocity (cm/s)	Average current direction (°true)	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)
03/20/83	10.36	19.91	2.18	124	15.3	15.4	15.2
03/21/83	9.45	16.66	2.88	293	15.3	15.4	15.1
03/22/83	8.39	11.72	4.64	148	15.5	15.6	15.4
03/23/83	9.29	17.63	2.19	155	15.4	15.5	15.3
03/24/83	14.42	30.57	4.05	244	15.5	15.6	15.4
03/25/83	5.51	10.01	1.43	054	15.5	15.6	15.4
03/26/83	15.63	33.42	2.17	107	15.6	15.7	15.3
03/27/83	13.58	24.11	4.10	259	15.2	15.5	14.9
03/28/83	6.48	11.91	2.16	240	15.4	15.6	15.1
03/29/83	9.80	18.01	2.95	141	15.4	15.6	15.0
03/30/83	8.47	16.67	2.94	121	15.3	15.4	15.2
03/31/83	10.21	18.39	2.18	284	15.3	15.4	15.1
04/01/83	10.00	20.63	3.50	115	15.5	15.6	15.3
04/02/83	16.87	34.40	3.21	250	15.6	15.9	15.4
04/03/83	8.27	17.42	2.19	132	15.5	15.6	15.4
04/04/83	10.39	21.25	2.19	109	15.6	15.7	15.5
04/05/83	11.17	18.58	2.37	111	15.8	16.0	15.7
04/06/83	7.08	14.76	2.01	159	15.9	16.0	15.8
04/07/83	10.85	29.41	2.16	123	16.1	16.5	15.8
04/08/83	8.25	23.32	2.75	210	16.6	17.0	16.2
04/09/83	19.81	40.49	6.57	238	18.0	18.4	16.8
04/10/83	9.13	26.58	2.17	296	17.9	18.7	16.8
04/11/83	8.57	17.04	2.93	270	18.3	18.8	17.0
04/12/83	7.47	16.68	2.17	066	17.6	18.9	16.8
04/13/83	11.58	17.05	5.95	107	17.0	17.5	16.6
04/14/83	9.74	21.04	2.15	134	17.5	18.5	16.7
04/15/83	12.96	28.29	3.06	196	19.0	19.5	18.3
04/16/83	6.87	16.10	2.38	274	18.1	18.9	17.7
04/17/83	7.84	23.72	2.14	277	18.0	18.4	17.6
04/18/83	8.88	17.05	2.13	242	18.1	18.3	17.8
04/19/83	10.32	18.58	2.76	126	17.8	18.1	17.2
04/20/83	9.26	18.20	2.18	104	17.9	18.1	17.7
04/21/83	10.17	21.42	2.18	137	17.8	17.9	17.7
04/22/83	7.24	14.19	2.11	120	17.7	17.9	17.5
04/23/83	14.34	28.48	2.12	236	17.9	18.6	17.6

Table 4.--Current direction, velocity, and water temperatures near Fourmile Point in Choctawhatchee Bay, Florida--Continued

Date	Average velocity (cm/s)	Maximum velocity (cm/s)	Minimum velocity (cm/s)	Average current direction (°true)	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)
04/24/83	6.93	17.99	2.74	034	18.2	18.6	17.9
04/25/83	8.06	13.62	3.11	124	17.9	18.4	17.7
04/26/83	7.21	15.15	2.18	108	18.0	18.4	17.8
04/27/83	6.93	12.48	2.19	111	18.0	18.0	17.9
04/28/83	6.09	11.34	2.19	097	18.0	18.0	17.9
04/29/83	7.02	12.67	2.14	124	17.9	18.0	17.9
04/30/83	6.03	13.02	2.19	131	17.9	18.0	17.9
05/01/83	4.71	10.19	2.16	105	17.9	18.0	17.9
05/02/83	6.04	12.10	2.81	115	17.9	18.0	17.9
05/03/83	7.49	15.89	2.68	256	18.1	18.6	17.9
05/04/83	5.96	11.91	2.36	077	18.0	18.3	17.9
05/05/83	8.86	21.63	2.16	246	18.3	19.4	17.9
05/06/83	9.04	13.63	2.19	138	18.4	19.0	18.0
05/07/83	7.77	12.86	2.19	166	19.0	20.0	18.5
05/08/83	8.34	15.73	2.19	272	18.8	19.8	18.5
05/09/83	9.69	15.91	3.33	165	18.6	19.3	18.3
05/10/83	5.64	9.82	2.38	182	18.8	19.1	18.7
07/14/83	6.97	11.31	2.18	309	26.0	26.3	25.8
07/15/83	6.01	10.19	2.06	205	26.2	26.6	25.9
07/16/83	5.88	11.53	1.79	318	26.6	27.1	26.1
07/17/83	6.18	12.32	1.64	037	26.1	26.6	26.0
07/18/83	7.17	14.22	1.59	273	26.2	26.6	26.0
07/19/83	7.53	11.46	2.65	247	26.5	26.8	26.0
07/20/83	4.51	8.24	2.09	049	26.7	27.0	26.5
07/21/83	5.36	8.67	2.13	008	26.8	27.0	26.6
07/22/83	6.17	14.15	1.44	046	26.7	27.2	26.3
07/23/83	8.28	13.71	3.68	255	26.6	27.5	26.2
07/24/83	8.40	14.35	2.94	155	26.6	26.8	26.3
07/25/83	8.05	14.78	3.08	053	26.6	26.8	26.5
07/26/83	8.24	15.84	3.14	244	26.7	26.9	26.6
07/27/83	7.51	13.05	2.95	286	27.0	27.5	26.8
07/28/83	8.28	12.01	3.89	318	27.2	27.5	26.8
07/29/83	8.56	13.00	3.49	301	27.3	27.6	27.1
07/30/83	7.99	15.93	1.88	075	27.6	27.9	27.3
07/31/83	8.88	13.40	5.71	334	27.4	27.9	27.1

Table 4. --Current direction, velocity, and water temperatures near Fourmile Point in Choctawhatchee Bay, Florida--Continued

Date	Average velocity (cm/s)	Maximum velocity (cm/s)	Minimum velocity (cm/s)	Average current direction (°true)	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)
08/01/83	6.64	11.22	2.95	090	27.4	27.5	27.4
08/02/83	6.83	10.79	1.43	024	27.4	27.8	27.2
08/03/83	6.97	10.53	2.51	021	27.5	28.0	27.3
08/04/83	6.69	21.81	2.17	009	27.5	28.1	27.3
08/05/83	5.80	11.34	2.14	225	27.3	27.5	27.2
08/06/83	6.77	12.35	2.18	033	27.5	28.0	27.2
08/07/83	6.89	12.29	1.99	244	27.4	28.0	27.2
08/08/83	7.78	12.10	4.27	279	27.6	27.9	27.3
08/09/83	5.85	9.81	2.16	252	27.4	27.8	27.3
08/10/83	6.25	10.39	2.95	280	27.5	27.8	27.2
08/11/83	7.94	14.19	1.46	340	27.5	27.9	27.3
08/12/83	7.38	12.28	2.17	208	27.6	28.0	27.4
08/13/83	6.93	13.05	2.56	005	27.6	27.9	27.5
08/14/83	8.25	12.08	2.72	279	27.7	28.0	27.5
08/15/83	7.99	13.02	2.10	312	28.4	28.7	28.0
08/16/83	6.55	9.99	3.52	096	28.2	28.7	28.0
08/17/83	3.95	7.53	2.13	072	28.0	28.2	27.9
08/18/83	4.68	9.62	2.15	264	28.0	28.2	27.8
08/19/83	4.03	7.70	1.67	027	27.9	28.1	27.8
08/20/83	5.39	9.82	2.76	320	28.0	28.2	27.8
08/21/83	5.24	9.52	2.12	329	28.0	28.4	27.9
08/22/83	5.88	10.64	2.18	241	28.1	28.4	27.9
08/23/83	7.61	10.38	4.84	307	28.8	29.1	28.3
08/24/83	5.49	8.80	2.16	059	28.4	28.7	28.2
08/25/83	6.75	11.14	2.16	267	28.4	28.7	28.1
08/26/83	9.13	16.59	2.57	310	29.0	29.4	28.6
08/27/83	7.40	12.87	2.37	097	29.3	29.6	29.1
08/28/83	7.75	11.53	2.95	088	29.0	29.1	29.0
08/29/83	6.43	20.30	2.14	227	28.9	29.1	28.8
08/30/83	4.00	6.96	2.09	130	28.9	29.0	28.8
08/31/83	4.09	7.14	1.92	244	29.0	29.2	28.9
09/01/83	8.04	18.37	2.53	302	29.2	29.4	29.0
09/02/83	7.10	16.29	2.18	091	29.6	29.8	29.4
09/03/83	4.40	8.48	2.16	206	29.2	29.5	29.0
09/04/83	7.36	14.19	2.18	038	29.2	29.6	29.0

Table 4.--Current direction, velocity, and water temperatures near Fourmile Point in Choctawhatchee Bay, Florida--Continued

Date	Average velocity (cm/s)	Maximum velocity (cm/s)	Minimum velocity (cm/s)	Average current direction (°true)	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)
09/05/83	9.05	19.30	2.76	281	29.3	29.6	29.0
09/06/83	6.96	10.86	2.19	122	29.4	29.5	29.4
09/07/83	5.60	8.86	2.18	352	29.4	29.6	29.3
09/08/83	4.82	10.01	2.15	162	29.4	29.5	29.3
09/09/83	5.93	8.86	2.12	282	29.4	29.5	29.3
09/10/83	5.23	9.05	2.02	319	29.5	29.6	29.4
09/11/83	7.15	16.26	2.17	002	29.5	29.7	29.4
09/12/83	8.06	16.85	2.91	311	29.4	29.5	29.3
09/13/83	10.79	17.21	6.19	290	29.4	29.5	29.3
09/14/83	7.04	11.53	3.71	213	29.3	29.3	29.3
09/15/83	7.56	9.43	5.05	244	29.4	29.4	29.3
09/16/83	6.09	11.15	2.18	235	29.3	29.4	29.2
09/17/83	4.24	8.67	2.06	025	29.3	29.3	29.2
09/18/83	5.98	9.61	2.94	164	29.3	29.3	29.3
09/19/83	4.65	8.29	1.78	088	29.2	29.3	29.1
09/20/83	5.63	10.95	1.86	006	29.2	29.3	29.1
09/21/83	7.84	13.61	2.75	042	29.1	29.2	28.8
09/22/83	7.75	13.97	4.46	144	29.0	29.1	29.0
09/23/83	6.09	10.24	1.66	122	28.8	29.0	28.3
09/24/83	8.17	14.39	4.05	101	28.3	28.8	27.0
09/25/83	7.75	13.96	3.90	090	27.3	28.0	25.5
09/26/83	5.56	10.38	1.52	121	26.2	27.0	25.0
09/27/83	6.18	9.81	2.19	100	25.9	26.6	24.9
09/28/83	4.75	8.85	2.08	118	25.9	26.7	25.1
09/29/83	4.75	8.45	2.17	095	26.2	27.1	25.1
09/30/83	4.09	7.34	2.12	351	26.5	26.8	26.1
10/01/83	3.53	5.98	1.56	093	27.0	27.8	25.9
10/02/83	4.23	7.87	2.18	101	26.9	27.8	26.2
10/03/83	4.22	7.53	2.13	285	26.2	27.0	25.7

## DISCUSSION ON POTENTIAL HEAT SOURCES

This section presents a brief discussion on the viability of potential heat sources in light of both the information available on the occurrence of the warming anomaly and knowledge about the hydrology, hydraulics, and hydrogeology of the Bay system. The following alternatives were considered as potential heat sources:

- I. Measurement Error
- II. Man-made Source
- III. Natural Source
  - A. Surface Water
  - B. Ground Water

### I. Instrument and/or Measurement Error

It is unlikely that measurement errors generated the uninterrupted pattern of rising temperatures observed in Figure 13. Generally, measurement errors of the magnitude observed display a discontinuous, random pattern. In addition, it would be very unlikely for the following events to take place concurrently:

- Two of the four crews registered the anomaly, and their monitoring areas were adjoining.
- Two crews using different sets of instruments recorded the anomaly which followed similar patterns and was observed over the same period of time.

--Temperatures began rising at about the same time at all stations.

--All stations for which the anomaly occurred were contiguous.

--The same crew with the same instrument registered the high temperatures at some stations but not at others.

--All instruments were re-calibrated and checked after acquisition.

Finally, the anomaly was again observed and documented a few weeks later at the East Pass station whereas no high temperatures were detected at the Santa Rosa Sound site at the same time using the same instruments.

## II. Man-made Source

As indicated in the discussion of a Heat Budget, the amount of heat released into the Bay over a four to 12 hour period is equivalent to the monthly production of thermoelectric energy for the entire state of Florida. It is difficult to envision how an operation causing temperatures of this magnitude would go unnoticed. Accordingly, it seems unlikely for such a large amount of energy to

have been not only generated but also wasted by man.

### III. Natural Source

#### A. Surface Water

The various sources of surface water in the Bay are the Choctawhatchee River, East Pass, Santa Rosa Sound, Intracoastal Waterway, and other streams. The Choctawhatchee River, Intracoastal Waterway, and Santa Rosa Sound may be immediately excluded from the list of heat sources since no temperature extremes were observed at those sites. The East Pass was flowing out of the Bay at the time the phenomenon occurred, indicating that the heat did not originate in the Gulf of Mexico but rather, within the Bay. Lastly, the cumulative flow of water from all the streams that empty into the Bay would be insufficient to produce such high temperatures. Our estimates indicate that between nine and 19 million cfs-°C of hot water inflow would be required to generate the observed temperatures. For water at 100°C (212°F) this translates into a flow of between 90,000 and 190,000 cfs, far exceeding the observed flows of the Bay. In addition, had the heat originated from the streams, the surface waters would have shown higher temperatures than bottom waters when the opposite actually occurred.

Perhaps the most important observation about surface water sources is that it would be practically impossible for the heat to have originated at a single location in the Bay. Instead, it would

have to have been discharged at many locations at the same time. This is a result of the constraints which the Bay's hydraulics poses on the distribution of heat. As mentioned earlier, peak velocities within the Bay rarely exceed one foot per second. Assuming that a point source of hot water existed at the center of the affected area and that water flowed constantly at one foot per second, it would have taken about ten hours for the heat to reach the perimeter of the hot area. From the observed data, the warming trend started at about the same time for most of the stations, and the maximum time differential observed at a couple of stations was in the order of one to two hours. Clearly, the heat source must have been of a distributed nature.

#### B. Ground Water

Due to the distribution of heat occurrence, ground water would appear to be a likely source of the hot water. Several factors point in that direction, as follows:

--Temperatures started rising at low tide when the East Pass was flowing out at peak velocities.

--The bottom waters experienced higher temperatures than mid-depth and surface waters, indicating that warming originated at the bottom.

--Warming of the bottom waters occurred simultaneously throughout the affected area, thus suggesting that warm ground water was discharged into the bottom of

the Bay throughout the affected area.

Although ground water seems to be the most feasible alternative, difficulty is encountered in determining the mechanism by which the hot water entered the Bay. The magnitude of the flow-temperature combination required to produce the warming of the Bay waters over a 12-hour period was estimated to be nine million cfs-°C. Assuming a water temperature of 100°C (212°F), the ground water flow into the Bay would have been in the order of 90,000 cfs.

That amount of flow over a 12-hour period would have caused the level of water in the Bay to rise by about 1.2 feet above the normal level. Since no such anomaly was observed in the water level data, as indicated in the water budget section, it must be concluded that the volume of ground water inflow to the Bay was negligible relative to that of the surface waters, and consequently, the hot waters do not seem to have originated from ground water inflow to the Bay.

## SUMMARY

Extremely high temperatures were recorded in the waters of Choctawhatchee Bay on two separate occasions. The first time, March 10, 1982, the anomaly was monitored throughout a 12-hour period. Two weeks later, March 24, 1982, high temperatures were again detected in the East Pass.

In order to document the occurrence, two temperature monitors were installed in the Bay as part of this investigation. No anomalous temperatures were recorded.

Calculations were performed using data from the 12-hour occurrence in order to quantify the amount of heat observed. The total amount of heat generated, equivalent to approximately 12.4 billion kilowatt-hours of energy, is comparable to the amount of thermoelectric energy generated by the state of Florida in a month. This result is only an estimate subject to the limitations inherent in using sparse data.

A brief discussion of the viability of potential heat sources was presented for the sake of argument. At this time, there is not sufficient data to fully explain the phenomenon or draw definitive conclusions as to its origin. Accordingly, it may be advisable that a temperature gage be installed in the Bay and be operated over a

period of several years.

## SELECTED REFERENCES

- Cox, R.A., and Smith, N.D., 1959, The Specific Heat of Sea Water: Proceedings of the Royal Society of London, Series A, Mathematics & Physical Sciences, Volume 252, No. 1268, pp. 51-62.
- Leach, S.D., 1983, Source, Use, and Disposition of Water in Florida, 1980: U.S. Geological Survey, Water-Resources Investigations 82-4090.
- Wagner, J.R., Lewis, C., Hayes, L.R., and Barr, D.E., 1980, Hydrologic Data for Okaloosa, Walton, and Southeastern Santa Rosa Counties, Florida: U.S. Geological Survey, Open-File Report 80-7 41.
- Barr, D.E., Maristany, A.E., and Kwader, T., 1981, Water Resources of Southern Okaloosa and Walton Counties, Northwest Florida: Northwest Florida Water Management District, Water Resources Assessment 81-1.
- Hayes, L.R., and Barr, D.E., 1983, Hydrology of the Sand-And-Gravel Aquifer, Southern Okaloosa and Walton Counties, Northwest Florida: U.S. Geological Survey, Water-Resources Investigations Report 82-4110.
- Smith, D.L., and Griffin, George M., Eds., The Geothermal Nature

of the Floridan Plateau: Florida Bureau of Geology, Special  
Publication No. 21, 1977.

APPENDIX A

Temperature and Conductance Data From  
Choctawhatchee Bay, March 9-10, 1982

Table 1.--Temperature and specific conductance at sites 11-15 in Choctawhatchee Bay, Florida, March 9-10, 1982

[All values at 0.8 total depth except as follows: T = top; M = middle]

Time	Temper- ature (°C)	Conduc- tance	Time	Temper- ature (°C)	Conduc- tance	Time	Temper- ature (°C)	Conduc- tance
Site 11			Site 12			Site 13		
1845	19.5	31,000	1830	19.0	29,500	1750	18.5	35,200
2050	19.0	31,000	2035	19.0	32,000	2015	20.0	36,500
2245	19.0	30,500	2125	19.5	31,500	2205	20.0	35,500
0055	19.5	30,000	0035	19.0	30,500	0005	20.0	36,500
0245	20.0	30,000	0230	19.5	33,000	0200	20.0	36,000
0500	19.5	29,500	0440	19.5	31,000	0415	19.0	35,500
0740	26.0	31,200	0720	24.0	31,500	0700	25.5	36,000
	(29.5T)	(10,500)		(25.5M)			(30.5T)	(15,300)
1040	23.0	29,300	0945	22.0	32,500	0900	25.0	35,500
1415	28.5	32,000		(24.5T)	(15,100)		(27.0T)	(15,500)
1640	43.0	33,500	1355	23.0	32,500	1320	29.5	36,000
				(30.0M)	(15,000)	1555	38.0	36,500
			1650	27.0	31,000			
				(31.0M)	(14,000)			
Site 14			Site 15					
1725	17.5	15,500	1700	19.0	33,000			
1950	19.0	16,500	1930	20.5	37,500			
2140	18.5	15,000	2130	21.5	37,000			
2330	19.0	17,000	2320	21.0	37,500			
0140	19.0	15,500	0125	20.5	37,500			
0355	18.5	15,000	0340	20.0	37,000			
0635	29.5	15,300	0620	22.0	37,100			
0835	31.5	15,200	0800	27.0	37,000			
1300	22.5	16,000		(28.5M)	(32,200)			
	(27.0	(16,000)	1240	28.0	37,000			
1530	27.0	15,500						
	(37.5M)	(15,500)	1500	30.0	37,000			

Table 2.--Temperature and specific conductance at sites 16-19 in  
Choctawhatchee Bay, Florida, March 9-10, 1982

[All values at 0.8 total depth except as follows: M = middle]

Time	Temperature (°C)	Conductance	Time	Temperature (°C)	Conductance
Site 16					
1730	15.0	36,200	1700	15.0	38,800
1940	15.0	35,200	1920	15.0	36,500
2140	15.0	28,400	2120	15.0	38,500
2325	14.0	15,000	2300	15.0	39,500
0130	15.0	--	0110	15.0	39,800
0340	14.5	20,200	0315	14.5	34,000
0535	23.0	37,000	0515	21.0	25,500
0745	28.0	37,000	0723	24.0	17,500
1054	27.0	35,800	1007	26.5	17,200
1455	27.0	36,000	1430	42.5	40,000
Site 18					
1740	15.0	36,000	1805	14.0	16,500
2000	15.0	36,500	2020	14.0	16,000
2153	14.0	16,500	2212	14.0	16,000
2342	14.0	16,300	0007	14.0	16,000
0143	15.0	35,000	0200	13.5	15,800
0355	14.5	35,000	0415	14.0	16,000
0605	17.0	36,500	0630	14.5	16,000
0803	28.0	37,000	0827	14.0	15,500
	(29.0M)	(18,000)	1400	16.0	16,200
1335	20.5	35,200	1535	15.5	16,200
1510	26.5	36,800			

APPENDIX B

Mini - Monitor Data at East Pass

and

Summaries of Fourmile Point Data

Table 2. Monthly summaries of velocity and water temperatures near Fourmile Point in Choctawhatchee Bay, Florida, 1983

Month	Average velocity (cm/s)	Maximum velocity (cm/s)	Minimum velocity (cm/s)	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)
March <sup>1</sup>	10.13	33.42	1.43	15.4	15.7	14.9
April	9.51	40.49	2.01	17.4	18.9	15.3
May	7.35	21.63	2.16	18.3	20.0	17.9
June			No record			
July <sup>1</sup>	7.22	15.93	1.44	26.7	28.1	25.8
August	6.43	21.81	1.43	28.0	29.6	27.2
September	6.49	19.30	1.52	28.7	29.7	24.9
October <sup>1</sup>	7.13	7.87	1.56	26.7	27.0	25.7

<sup>1</sup>Partial record for month.

Table 3. Average current speed, direction, and range of water temperature near Fourmile Point in Choctawhatchee Bay, Florida

Period	Average current (cm/s)	Average current direction	Temperature (°C)	
			Minimum	Maximum
03/19/83-05/10/83	2.19	162.8	14.9	20.0
07/14/83-10/03/83	0.44	348.8	24.9	29.7

United States Department of Interior - Geological Survey  
 Process Date is 05-02-84  
 Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
 Latitude 30°23'35" Longitude 086°31'16" Drainage Area Datum State 12 County 091  
 Source Agency USGS

Temperature, Water (Deg. C), Water Year October 1981 to September 1982  
 Sampling Depth 30.00 (ft.)  
 Provisional Data

Day	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
	April	May	June	July	Aug.	Sept.						
1	22.0	21.0	29.0	27.0	24.0	24.0	29.0	29.0	30.5	30.5	29.0	29.0
2	22.0	21.0	29.0	27.0	24.0	24.0	29.5	29.5	30.5	30.5	29.5	29.5
3	22.5	21.5	29.0	27.5	23.5	23.5	29.5	29.5	30.5	30.5	29.5	29.5
4	23.0	21.0	29.5	28.0	24.0	24.0	29.5	29.5	30.0	30.0	28.5	28.5
5	23.5	21.5	29.0	27.0	24.0	24.0	29.5	29.5	29.5	29.5	27.5	27.5
6	24.5	22.5	28.5	26.5	23.5	23.5	29.0	29.0	29.5	29.5	27.5	27.5
7	24.5	22.0	28.5	26.5	24.5	24.5	29.5	29.5	29.0	29.0	27.0	27.0
8	24.0	22.5	28.5	26.0	29.5	28.0	29.5	29.5	28.5	28.5	26.5	26.5
9	24.0	22.5	28.5	25.0	29.5	28.5	29.5	29.5	28.5	28.5	25.5	25.5
10	24.0	22.5	28.5	25.0	29.5	28.5	29.5	29.5	28.0	28.0	25.5	25.5
11	24.0	22.5	28.5	25.0	29.5	28.5	29.5	29.5	28.0	28.0	26.0	26.0
12	24.5	23.0	29.0	24.0	29.5	28.5	29.5	29.5	28.0	28.0	26.5	26.5
13	25.0	23.0	28.5	24.5	29.5	28.5	29.5	29.5	28.5	28.5	27.0	27.0
14	25.0	23.5	29.0	24.5	29.0	29.0	29.5	29.5	29.0	29.0	28.0	28.0
15	25.0	23.5	28.5	24.0	29.5	28.5	29.5	29.5	29.0	29.0	28.5	28.5
16	25.5	24.0	28.0	26.0	29.5	28.0	29.5	29.5	28.0	28.0	26.0	26.0
17	25.5	24.0	28.5	23.5	30.0	29.0	30.0	30.0	29.0	29.0	28.5	28.5
18	26.0	25.0	28.5	25.5	30.0	29.0	30.0	30.0	29.0	29.0	28.5	28.5
19	26.0	25.0	28.5	27.0	30.0	29.0	30.0	30.0	29.0	29.0	28.5	28.5
20	22.5	22.0	25.0	28.5	27.0	30.0	29.0	30.0	29.0	29.0	28.5	28.5
21	24.0	22.0	27.0	25.0	29.0	27.0	30.0	29.0	30.5	30.0	28.5	28.5
22	23.0	21.0	27.0	24.0	29.5	27.5	30.0	29.0	30.5	29.0	27.5	27.5
23	22.0	21.0	27.5	24.5	29.5	27.0	30.0	29.0	30.0	29.0	27.5	24.5
24	21.5	20.5	27.5	25.5	29.5	28.0	30.0	29.0	30.5	29.0	27.0	24.0
25	21.0	20.5	27.0	26.0	30.0	28.5	29.5	29.5	30.0	29.0	27.0	23.5
26	22.0	20.5	28.0	26.0	30.0	28.5	29.0	28.0	---	---	26.5	23.5
27	22.0	20.5	28.0	26.5	29.0	27.5	29.5	28.5	30.5	30.0	27.0	24.0
28	21.5	20.5	28.0	26.5	29.0	27.0	29.0	29.0	30.5	29.5	27.0	24.0
29	22.0	20.5	29.0	26.5	29.0	28.0	29.0	29.0	30.5	29.0	27.0	24.0
30	22.0	20.5	28.5	27.0	28.5	26.0	29.5	29.5	30.0	29.0	27.0	24.0
31	---	---	28.5	27.5	---	---	29.0	28.0	30.0	29.0	---	---
MONTH	24.0	20.5	29.0	21.0	30.0	23.5	30.0	23.5	30.5	28.5	30.5	23.5
YEAR	30.5	20.5										

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

United States Department of Interior - Geological Survey  
 Process Date is 05-02-84  
 Station Number 30235086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
 Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 091  
 Source Agency USGS

Temperature, Water (Deg. C), Water Year October 1982 to September 1983  
 Sampling Depth 30.00 (ft.)  
 Provisional Data

Day	Max	Min	Max	Min								
	Oct.		Nov.		Dec.		Jan.		Feb.		March	
1	27.0	26.5	23.0	20.0	19.0	17.5	14.0	14.5	14.0	13.0	12.0	
2	27.0	26.0	23.5	20.5	19.5	17.5	14.5	14.5	12.5	14.0	12.5	
3	26.5	24.0	23.0	21.0	20.0	18.0	13.0	12.5	12.0	14.5	13.5	
4	26.5	24.0	23.0	20.0	21.0	20.5	18.5	12.5	12.5	11.5	13.0	
5	26.0	24.0	21.5	17.5	21.0	20.5	16.5	12.5	13.5	11.5	16.0	15.5
6	26.0	24.0	21.5	17.0	21.0	19.5	17.5	12.0	13.5	11.0	16.5	15.0
7	26.5	24.5	21.0	16.5	21.0	18.5	18.0	11.5	13.5	11.0	17.5	15.5
8	26.5	25.5	20.5	16.5	21.0	18.5	18.0	12.5	14.0	10.5	17.5	16.5
9	27.0	26.0	20.5	16.5	21.0	18.0	18.0	12.5	14.0	11.0	17.0	15.5
10	27.0	26.5	20.5	17.0	20.5	19.0	17.5	13.0	14.5	11.5	15.0	13.5
11	27.0	26.5	21.0	20.0	20.5	18.0	17.0	13.0	14.0	11.5	14.5	13.0
12	27.5	27.0	21.5	17.5	18.0	16.0	16.5	12.5	14.5	11.5	14.5	12.5
13	27.0	26.0	21.0	17.0	18.5	15.5	17.0	11.5	14.0	11.0	15.0	12.5
14	26.5	24.0	21.0	16.5	18.5	14.5	17.0	12.0	14.0	10.5	15.0	13.5
15	26.5	24.0	20.0	15.5	19.0	14.5	17.5	11.5	14.5	11.0	15.0	13.5
16	25.5	23.0	20.0	15.5	19.0	14.5	17.0	11.0	14.5	13.0	14.5	
17	25.5	20.5	15.5	17.5	13.0	16.5	10.5	14.5	12.0	15.5	14.0	
18	25.0	22.5	19.5	16.0	16.5	12.5	16.5	10.0	14.5	12.0	14.5	12.5
19	25.0	22.0	20.0	16.0	17.0	13.0	16.0	9.5	15.0	12.5	15.5	14.0
20	25.0	22.0	20.0	16.5	17.0	12.5	14.0	13.0	15.5	13.0	15.5	14.0
21	25.0	22.0	20.0	17.5	17.5	12.5	13.5	9.0	15.5	13.5	15.5	14.0
22	25.0	21.5	20.0	17.5	17.5	13.0	14.5	9.0	15.0	14.0	15.0	13.5
23	24.5	20.5	19.5	16.5	18.5	14.0	14.5	9.0	15.5	14.0	15.0	13.5
24	24.5	20.0	20.0	18.5	17.5	17.0	15.0	9.0	16.0	14.5	15.0	13.0
25	23.5	19.5	19.5	18.0	17.5	14.5	14.5	9.5	15.5	14.5	15.0	12.5
26	23.0	19.0	19.5	18.5	17.5	15.0	14.0	9.5	15.5	13.5	14.5	13.0
27	22.5	19.0	19.5	19.0	17.5	15.5	14.0	10.0	14.0	12.0	15.0	13.0
28	23.0	20.5	19.5	19.0	17.0	16.5	14.0	9.5	15.5	12.0	14.5	13.5
29	23.0	22.5	19.5	18.5	17.0	16.0	14.0	10.0	10.0	---	14.0	13.5
30	23.0	21.5	20.0	18.5	17.5	15.0	14.0	10.5	10.5	---	15.0	14.0
31	23.0	19.5	---	---	17.5	14.5	14.0	12.0	---	---	15.5	14.0
MONTH	27.5	19.0	23.5	15.5	21.0	12.5	18.5	9.0	16.0	10.5	17.5	12.0

United States Department of Interior - Geological Survey  
Process Date is 05-02-84  
Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 091  
Source Agency USGS

Temperature, Water (Deg. C), Water Year October 1982 to September 1983  
Sampling Depth 30.00 (ft.)  
Professional Data  
Provisional

Day	April			May			June			July			Aug.			Sept.		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Max	Min	Max	Min
1	15.5	14.0	21.5	20.0	26.0	22.5	29.0	26.0	27.0	27.5	27.0	28.0	29.5	28.5	28.5	28.0	28.0	28.0
2	15.5	14.5	22.0	20.5	26.0	22.5	29.5	27.0	27.5	27.0	27.5	28.0	28.5	28.5	28.5	28.0	28.0	28.0
3	15.5	14.0	21.5	21.0	26.5	24.0	30.0	28.0	28.0	27.5	26.5	28.0	28.5	28.5	28.5	28.0	28.0	28.0
4	16.0	14.5	21.5	20.5	26.0	25.0	29.5	28.5	28.0	27.0	27.0	28.0	28.5	28.5	28.5	28.0	28.0	28.0
5	16.0	15.0	21.5	20.0	25.5	25.0	29.5	28.0	28.0	27.5	27.5	29.0	29.0	29.0	29.0	27.5	27.5	27.5
6	17.0	16.0	21.5	19.5	26.5	24.5	29.0	27.0	28.0	27.5	27.5	28.0	28.5	28.5	28.5	27.0	27.0	27.0
7	17.0	17.0	21.5	21.0	26.0	24.0	28.5	27.0	28.5	27.5	27.5	28.0	29.0	29.0	29.0	27.0	27.0	27.0
8	17.5	16.5	21.5	21.5	26.5	21.0	28.5	27.5	28.5	27.5	27.5	28.5	29.0	29.0	29.0	27.0	27.0	27.0
9	18.0	17.0	21.5	20.5	26.0	23.0	28.0	27.5	28.5	27.5	27.5	29.0	29.0	29.0	29.0	27.0	27.0	27.0
10	17.5	16.5	23.0	20.5	26.0	22.5	28.5	27.5	29.0	27.5	27.5	29.0	29.0	29.0	29.0	27.5	27.5	27.5
11	18.0	17.0	22.5	21.5	26.5	23.5	29.0	27.5	27.5	28.0	28.0	28.5	28.5	28.5	28.5	27.5	27.5	27.5
12	18.0	16.5	24.5	22.5	26.5	24.0	29.0	28.0	28.5	27.5	27.5	28.0	28.5	28.5	28.5	27.0	27.0	27.0
13	19.0	17.0	25.0	22.5	26.5	24.0	29.0	28.0	29.0	28.0	29.0	29.5	29.5	29.5	29.5	27.5	27.5	27.5
14	18.5	18.0	25.5	22.5	26.5	24.5	29.0	28.0	28.5	27.0	27.0	27.5	27.5	27.5	27.5	25.5	25.5	25.5
15	19.0	18.0	25.0	23.5	27.0	25.0	28.5	27.0	28.5	27.5	27.5	28.0	28.5	28.5	28.5	26.0	26.0	26.0
16	18.0	17.0	25.5	23.5	27.5	25.0	28.5	27.0	28.5	27.5	27.5	28.0	28.5	28.5	28.5	26.0	26.0	26.0
17	18.0	16.5	24.5	23.0	27.0	25.0	29.0	27.0	28.5	27.5	27.5	28.0	28.5	28.5	28.5	26.0	26.0	26.0
18	17.5	16.5	24.0	23.0	27.0	25.0	29.0	27.5	28.5	27.5	27.5	28.0	28.0	28.0	28.0	26.5	26.5	26.5
19	17.0	16.0	24.0	23.0	27.0	25.5	28.5	26.5	29.5	28.5	28.5	29.0	29.0	29.0	29.0	27.0	27.0	27.0
20	17.0	16.0	24.0	23.0	26.0	25.5	29.0	25.0	29.5	28.5	29.5	29.5	29.5	29.5	29.5	27.5	27.5	27.5
21	17.5	16.0	24.0	23.5	25.5	25.0	29.5	26.0	29.5	27.0	27.0	29.5	28.5	28.5	28.5	27.0	25.0	25.0
22	17.0	16.5	24.0	24.0	26.5	25.0	29.5	26.0	29.5	27.0	27.0	29.5	28.0	28.0	28.0	26.0	22.5	22.5
23	17.5	17.0	25.5	23.0	26.5	25.5	29.0	26.0	29.0	27.0	27.0	29.0	29.5	29.5	29.5	26.0	22.0	22.0
24	18.0	17.0	26.0	24.0	26.5	26.0	28.5	26.5	28.5	24.5	24.5	29.0	29.0	29.0	29.0	25.5	21.5	21.5
25	17.0	16.5	25.0	23.5	27.0	26.0	28.5	24.0	28.5	24.0	24.0	29.0	29.0	29.0	29.0	25.5	21.5	21.5
26	17.5	16.5	25.0	23.5	28.0	26.0	28.5	23.0	29.5	23.0	23.0	29.5	28.5	28.5	28.5	22.0	21.5	21.5
27	18.5	17.0	25.0	23.5	28.0	26.5	29.0	24.0	29.5	24.0	24.0	29.5	28.0	28.0	28.0	25.0	21.5	21.5
28	19.0	17.5	25.5	23.0	28.0	26.0	29.5	25.0	29.5	25.0	25.0	29.5	29.0	29.0	29.0	25.0	21.5	21.5
29	20.0	18.0	25.5	23.5	29.0	26.5	29.5	27.0	29.0	27.0	27.0	29.5	28.5	28.5	28.5	25.0	21.5	21.5
30	21.0	19.5	25.5	23.0	29.0	27.0	28.5	27.0	28.5	27.0	27.0	29.0	28.0	28.0	28.0	24.5	22.0	22.0
31	---	26.0	22.5	---	---	---	---	28.5	27.5	28.5	27.5	29.5	28.5	28.5	28.5	---	---	---
MONT	21.0	14.0	26.0	19.5	29.0	21.0	30.0	23.0	30.0	26.5	26.5	29.5	29.5	29.5	29.5	21.5	21.5	21.5

United States Department of Interior - Geological Survey  
Process Date is 05-02-84  
Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 091  
Source Agency USGS

Temperature, Water (Deg. C), Water Year October 1983 to September 1984  
Sampling Depth 30.00 (ft.)  
Professional Data

United States Department of Interior - Geological Survey  
 Process Date is 05-02-84  
 Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
 Latitude 30°23'35" Longitude 086°31'16" Drainage Area Datum State 12 County 091  
 Source Agency USGS

Specific Conductance (Microhos/cm at 25 Deg. C), Water Year October 1981 to September 1982  
 Sampling Depth 30.00 (ft.)  
 Provisional Data

Day	Max	Min	Sept.											
	April		May		June		July		Aug.					
1	---	---	46900	25300	46600	30100	43800	30400	---	---	48400	25100		
2	---	---	42000	24000	48500	30700	47200	29600	---	---	47900	26700		
3	---	---	38900	21400	48300	30800	47400	28700	---	---	48000	26400		
4	---	---	39200	21300	46500	30200	47600	28700	---	---	47200	25600		
5	---	---	39000	21300	45300	30200	47900	29900	---	---	47200	24200		
6	---	---	37900	20800	46100	28800	47700	34200	---	---	48100	25300		
7	---	---	46400	26700	46700	28100	47400	31100	---	---	47900	26700		
8	---	---	46300	23500	45600	29000	47900	28900	---	---	48800	26900		
9	---	---	47000	22700	46200	35000	46400	25800	---	---	48800	27000		
10	---	---	47700	22300	49300	36300	45100	25500	---	---	48700	27100		
11	---	---	47800	22400	47900	36500	44300	28400	---	---	48600	25900		
12	---	---	46500	22900	48100	34600	43600	28500	---	---	45900	27400		
13	---	---	47400	22800	48500	36200	43800	30700	42500	20000	48600	27100		
14	---	---	48100	22800	48300	35500	43800	31100	44000	20300	48900	27700		
15	---	---	48200	23900	48700	32500	44200	25600	44100	19700	48600	27000		
16	---	---	48300	23500	48600	40700	43900	28200	43200	20500	49200	27200		
17	---	---	47900	23400	48700	36600	44400	26700	43200	20100	49200	27900		
18	---	---	47700	24400	47200	32200	44500	24800	44100	18100	48900	27900		
19	---	---	47500	32400	45400	34000	44700	24200	44300	17300	49300	29700		
20	46600	42100	48300	26700	45300	35500	44400	23900	44100	18100	49200	29700		
21	46000	19500	48300	29400	45800	34300	44300	25200	44500	19500	49800	29400		
22	46000	19300	48000	26400	44300	35600	44200	24500	44500	18700	49700	29900		
23	46800	23100	48100	24700	46000	34500	44700	28900	42700	27100	49800	31000		
24	46300	21900	44800	27200	46600	29800	44600	34200	43500	21900	49100	29800		
25	47000	17300	46800	24600	44800	28600	44000	38200	44700	25500	49600	30200		
26	47100	19000	44900	23100	40600	26600	38500	33900	---	---	48900	29800		
27	47600	20900	46000	24500	40100	30900	41900	25700	50100	25300	49300	30500		
28	45100	17900	46300	33200	37800	32000	43700	27300	50300	26800	49000	30300		
29	46300	21800	46000	32600	43500	38200	44600	29600	51800	24900	49200	29200		
30	46400	25200	46500	34600	46100	31700	44100	29200	47900	25100	49500	28700		
31	---	---	47000	27700	---	---	42400	31500	48800	24900	---	---	---	
MONTH	47600	17300	48300	20800	49300	26600	47900	23900	51800	17300	49800	24200		
YEAR	51800	17300												

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

United States Department of Interior - Geological Survey  
 Process Date is 05-02-84  
 Station Number 30233586311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
 Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 091  
 Source Agency USGS

Specific Conductance (Micromhos/cm at 25 Deg. C), Water Year October 1982 to September 1983  
 Sampling Depth 30.00 (ft.)  
 Provisional Data

Day	Max	Min	Max	Min										
	Oct.		Nov.		Dec.		Jan.		Feb.		March			
1	50500	44500	50500	34100	47300	34300	48500	26400	46400	44100	22500	21200		
2	50600	49000	50200	34000	47100	33600	48700	25300	45300	22700	50700	22200		
3	50500	39300	50300	34200	47300	34100	49000	26500	28300	24800	52700	23300		
4	50200	30400	50700	33800	47600	34200	49700	26400	29000	23400	52100	23700		
5	50000	29600	51100	34500	48200	33200	48000	26700	45200	23500	53500	23600		
6	49800	30000	51100	35500	48500	34500	48900	26000	45000	23700	51800	21900		
7	49000	39400	51100	34800	48500	34600	50000	26300	43500	22500	52100	19700		
8	48900	31500	50600	35200	49300	34800	49800	25300	43400	22600	51400	19200		
9	48400	31200	50600	35000	50100	35000	49500	21500	43600	22600	50600	23200		
10	48800	30900	50700	34900	50200	47400	49800	18000	44300	20200	53700	24700		
11	50100	31900	51200	48300	49300	34900	47700	15100	42500	15300	53600	23800		
12	50100	32300	51200	33400	35700	34500	50100	23500	42900	16000	55900	22900		
13	49300	28300	50700	32900	46800	35300	50200	24400	41100	14700	55000	24400		
14	50200	29500	50300	32700	49600	35600	49400	25800	42300	14500	52500	25000		
15	50400	33300	50000	32300	49700	35500	51200	23800	43000	16400	55300	24800		
16	48100	20600	50000	33100	50500	32500	51000	24200	43000	28700	56000	16700		
17	49100	31100	50000	33200	50100	32600	51100	25000	42500	13800	53800	16400		
18	49500	32800	49700	33000	49800	32900	51200	23200	42100	13200	20900	16200		
19	50000	32700	49900	33200	49100	31300	51100	22500	37200	13100	53900	18700		
20	50000	31600	49900	33300	49300	31100	50600	50000	41000	13900	50600	19000		
21	49900	30900	49800	32400	49400	32900	50000	23400	52400	12300	51300	18600		
22	50300	30200	49700	32300	49900	32000	50400	23400	51400	16200	48700	19600		
23	50300	28600	49500	32000	50100	31600	50500	22500	49800	16400	52100	19300		
24	50100	33800	47300	31000	48800	50100	48000	23100	49900	16300	51300	15400		
25	49700	33600	47200	34400	49200	25000	48900	23700	52700	17200	51200	18400		
26	49400	33300	47300	45400	48900	24900	49000	24200	52400	17000	52500	19200		
27	49300	33600	47300	45500	48200	25500	49000	24800	52800	19500	52300	18900		
28	49400	45000	47400	44900	47300	24900	48200	23800	53100	20500	38700	20600		
29	49900	49100	47200	32700	47900	24100	45900	24200	49900	22100	21400			
30	49700	41200	47200	33900	48400	25600	46500	23300	51400	20300				
31	50900	21700	---	---	48800	26100	46700	23900	---	---	51900	17500		
MONTH	50900	27100	51200	31000	50500	24100	51200	15100	53100	12300	56000	15400		

United States Department of Interior - Geological Survey  
Process Date is 05-02-84.  
Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 091  
Source Agency USGS

Specific Conductance (Micromhos/cm at 25 Deg. C.) Water Year October 1982 to September 1983  
Sampling Depth 30' (ft.)  
Provisional Data

United States Department of Interior - Geological Survey  
Process Date is 05-02-84  
Station Number 30233508631601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 302335 Longitude 086316 Drainage Area Datum State 12 County 091  
Source Agency USGS

Specific Conductance (Micromhos/cm at 25 Deg. C.), Water Year October 1983 to September 1984  
Sampling Depth 30.00 ft.  
Provisional Data

United States Department of Interior - Geological Survey  
 Process Date is 05-03-84  
 Station Number 30235086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
 Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 09L  
 Source Agency USGS

Temperature, Water (Deg. C), Water Year October 1981 to September 1982  
 Sampling Depth 16.00 (ft.)  
 Provisional Data

Day	Max	Min	April	May	June	July	Aug.	Sept.
1	---	---	22.0	21.0	29.0	27.0	---	30.5 29.0
2	---	---	22.0	21.0	29.0	27.0	---	30.5 29.0
3	---	---	23.0	21.5	29.0	27.5	---	30.5 29.0
4	---	---	23.5	21.0	30.0	28.0	---	30.5 28.5
5	---	---	23.5	21.5	29.5	27.0	---	29.5 27.5
6	---	---	24.5	22.5	28.5	26.5	---	29.5 27.0
7	---	---	23.5	22.5	28.5	27.0	---	29.0 26.5
8	---	---	24.0	22.0	29.0	26.5	---	28.5 26.0
9	---	---	24.0	22.0	---	---	---	28.0 25.5
10	---	---	24.5	22.5	---	---	---	27.5 25.5
11	---	---	24.5	23.0	---	---	---	27.5 25.5
12	---	---	25.0	23.0	---	---	---	28.0 26.5
13	---	---	25.0	23.0	---	---	---	28.5 27.0
14	---	---	25.0	23.5	---	---	---	29.0 28.0
15	---	---	25.0	23.5	---	---	---	29.5 28.5
16	---	---	25.5	24.0	---	---	---	29.5 28.5
17	---	---	26.0	24.0	---	---	---	29.0 28.5
18	---	---	26.0	25.0	---	---	---	29.5 28.5
19	---	---	26.0	25.0	---	---	---	29.5 28.5
20	25.0	22.0	27.5	25.0	---	---	---	29.0 28.0
21	24.0	22.0	27.0	24.5	---	---	---	28.5 28.0
22	23.0	21.5	27.0	24.0	---	---	---	27.5 25.5
23	22.0	20.5	27.5	24.5	---	---	---	27.0 24.0
24	21.0	20.5	28.0	25.5	---	---	---	27.0 24.0
25	21.0	20.5	27.5	26.0	---	---	---	27.0 23.5
26	22.0	20.5	28.0	26.0	---	---	---	26.5 23.5
27	22.5	20.5	28.5	26.5	---	---	30.5 29.5	26.5 23.5
28	22.0	20.5	28.5	26.5	---	---	30.5 29.5	27.0 24.0
29	22.0	20.5	29.5	26.5	---	---	30.5 29.0	27.0 24.0
30	22.0	20.5	29.0	27.0	---	---	30.0 29.0	27.0 24.0
31	---	---	28.5	27.5	---	---	30.0 29.0	---
MONTH	24.0	20.5	29.5	21.0	30.0	26.5	30.5	29.0 30.5 23.5
YEAR	30.5	20.5						

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

United States Department of Interior - Geological Survey  
 Process Date is 05-03-84  
 Station Number 30233508611601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
 Latitude 30°23'35" Longitude 086°31'6" Drainage Area Datum State 12 County 091  
 Source Agency USGS

Temperature, Water (Deg. C), Water Year October 1982 to September 1983  
 Sampling Depth 16.00 (ft.)  
 Provisional Data

Day	Max	Min	Max	Min								
	Oct.		Nov.		Dec.		Jan.		Feb.		March	
1	27.0	25.0	23.0	20.0	20.0	19.0	17.0	14.0	14.5	14.0	13.0	12.0
2	27.0	26.0	23.5	20.5	20.5	19.5	17.0	14.0	14.5	12.5	14.5	12.5
3	26.5	24.0	21.0	21.0	21.0	19.5	18.0	15.0	12.5	12.0	15.0	13.5
4	26.5	23.5	23.0	19.5	21.0	20.5	18.0	12.5	12.5	11.5	15.5	13.5
5	26.0	24.0	21.5	17.5	21.0	20.0	16.5	12.5	15.5	11.0	16.0	15.0
6	26.0	24.0	21.5	19.0	21.0	19.5	17.5	12.0	13.5	11.5	16.5	15.0
7	26.0	24.5	21.0	16.5	20.5	18.5	18.0	11.5	13.0	11.0	17.5	16.0
8	26.5	25.5	20.5	16.5	21.0	18.5	18.0	12.5	13.5	10.5	18.0	16.5
9	27.0	25.5	20.5	16.5	21.0	18.0	18.0	12.5	14.0	11.0	17.0	15.5
10	27.0	26.0	20.5	17.0	20.5	18.0	17.5	13.0	14.5	11.5	15.0	13.5
11	27.0	26.0	21.0	19.0	20.5	18.0	17.0	12.5	14.0	11.5	14.5	13.0
12	27.0	26.5	21.5	17.5	18.0	16.0	16.0	12.5	14.5	11.5	14.5	12.5
13	27.0	26.0	21.0	17.0	18.0	15.5	17.0	11.5	14.0	11.0	15.0	12.5
14	26.5	24.0	21.0	16.5	18.5	14.5	16.5	12.0	14.0	10.5	15.0	13.0
15	26.5	23.0	20.0	15.5	18.5	14.5	17.5	11.5	14.5	10.5	15.0	13.5
16	25.0	22.0	20.0	15.5	18.5	14.5	17.0	11.0	14.5	12.0	15.0	14.0
17	25.5	22.5	20.5	15.0	17.5	13.0	16.5	10.5	14.0	12.0	15.0	14.0
18	25.0	22.0	19.5	15.5	16.5	12.5	16.5	10.0	14.5	12.0	14.5	14.0
19	25.0	22.0	20.0	16.0	17.0	13.0	16.0	9.5	15.0	12.5	15.5	14.0
20	25.0	22.0	20.0	16.5	17.0	12.5	14.0	13.0	15.5	13.0	16.5	15.0
21	25.0	22.0	20.0	17.0	17.5	12.5	13.5	9.0	15.5	13.5	16.0	14.5
22	24.5	21.5	20.0	17.5	17.5	13.0	14.5	9.0	15.0	14.0	16.0	14.5
23	24.5	20.5	20.0	18.0	17.5	13.0	14.5	9.0	15.5	14.0	16.0	14.0
24	24.5	20.0	20.0	18.5	17.5	16.0	14.5	9.0	16.0	14.5	15.5	13.5
25	23.5	19.0	19.5	17.5	17.5	14.5	14.5	9.5	15.5	14.0	15.5	13.5
26	23.0	18.5	19.0	18.0	17.5	15.0	14.0	9.5	15.5	13.5	15.5	13.5
27	22.5	19.0	19.0	17.5	17.0	15.5	14.0	10.0	14.0	11.5	16.0	14.0
28	22.5	20.5	19.5	18.5	18.5	16.5	13.5	9.5	13.5	12.0	15.5	14.5
29	23.0	22.5	19.5	18.5	17.0	16.0	14.0	10.0	---	---	15.0	14.0
30	23.0	19.5	19.5	18.5	17.5	15.0	14.0	10.5	---	---	15.5	14.5
31	23.0	19.5	---	---	---	17.5	14.5	14.0	12.0	---	16.5	14.5
MONTH	27.0	18.5	23.5	15.5	21.0	12.5	18.0	9.0	16.0	10.5	18.0	12.0

United States Department of Interior - Geological Survey  
Process Date is 05-03-84  
Station Number 30233086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 091  
Source Agency USGS

Temperature, Water (Deg. C), Water Year October 1982 to September 1983  
Sampling Depth 16.00 (ft.)  
Professional Data  
Produced by

United States Department of Interior - Geological Survey  
Process Date is 05-03-84  
Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 302335 Longitude 0836116 Drainage Area Datum State 12 County 091  
Source Agency USGS

Temperature, Water (Deg. C), Water Year October 1983 to September 1984  
Sampling Depth 16.00 (ft.)  
Provisional Data

United States Department of Interior - Geological Survey  
 Process Date is 05-03-84  
 Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
 Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 091 Source Agency USGS

Specific Conductance (Micromhos/cm at 25 Deg. C), Water Year October 1981 to September 1982  
 Sampling Depth 16.00 (ft.)  
 Provisional Data

Day	Max	Min										
	April		May		June		July		Aug.		Sept.	
1	---	---	46800	25900	43900	28600	47200	32500	---	---	50600	26200
2	---	---	46800	26100	46500	29600	46800	29800	---	---	50100	26400
3	---	---	46500	25600	45800	29900	48800	30300	---	---	50000	27400
4	---	---	46800	25100	45600	33500	48800	30400	---	---	49800	26300
5	---	---	46800	25200	48200	31700	46700	30400	---	---	49100	26500
6	---	---	45800	24800	48200	31200	46800	32400	---	---	50100	27300
7	---	---	47400	23200	48700	31600	46200	31300	---	---	50100	28300
8	---	---	47400	23400	48600	32100	46500	29000	---	---	51100	27900
9	---	---	47200	23200	47300	32300	45200	28500	---	---	51000	28200
10	---	---	47100	24400	47600	35400	44000	26400	---	---	50300	28300
11	---	---	47000	23900	48200	35600	43000	26300	---	---	50700	28300
12	---	---	46800	23200	47500	34400	43000	26200	---	---	47000	28400
13	---	---	46500	23400	46900	35000	43400	28900	30700	16600	50800	28900
14	---	---	47200	23400	46700	35400	43000	28700	40000	16800	51000	28300
15	---	---	47300	23300	48900	34600	44100	26500	40000	16800	50400	27600
16	---	---	46900	22700	48200	36300	43700	25200	39200	17000	50700	27600
17	---	---	47000	23500	48200	36400	43500	25100	38800	17300	50700	28400
18	---	---	46300	23300	47100	32700	43400	24100	38700	15300	50500	28900
19	---	---	46200	27200	44700	34700	43200	24200	38900	14900	50500	29700
20	47000	26700	46300	25900	45500	34200	42400	28800	38100	15100	50300	30400
21	46700	19700	46200	27900	45200	34300	42000	22800	38300	15700	51300	30100
22	46800	19600	46000	25400	43300	34600	42500	23300	38500	19700	51100	31000
23	47600	20000	45700	25300	44400	33400	41900	26000	35700	20300	51100	31900
24	47600	21100	45900	25800	44700	31700	42300	35600	36100	18500	50600	30700
25	47600	22200	45600	24300	44200	29600	42000	34400	33500	20100	50700	31200
26	47600	22400	45200	23700	44500	26400	35200	28700	---	---	50400	30800
27	47900	22600	46100	25000	41200	29200	38900	27200	53300	25300	50500	30700
28	47800	23200	44800	28600	36600	33300	40700	29900	53700	26800	49600	30600
29	47100	24700	44900	30800	42700	37100	41300	27500	54400	25400	49900	29900
30	47200	25900	45100	29900	45800	31200	40800	26300	50300	26200	50300	29600
31	---	---	46000	27800	---	---	38500	28100	51200	25700	---	---
MONTH	47900	19600	47400	22700	48900	26400	48800	22800	54400	14900	51300	26200
YEAR	54400	14900										

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20

United States Department of Interior - Geological Survey  
Process Date is 05-03-84  
Station Number 302335086211601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 302335 Longitude 0863116 Drainage Area Datum State 12 County 091  
Source Agency USGS

Specific Conductance (Micromhos/cm at 25 Deg. C.); Water Year October 1982 to September 1983  
 Sampling Depth 16.00 (ft.)  
 Provisional Data

Day	Max	Min	Oct.	Nov.	Dec.	Jan.			Feb.			March		
						Max	Min	Max	Max	Min	Max	Max	Min	Min
1	51200	33000	52000	35000	49300	35300	50200	27400	51100	44400	21800	21400		
2	51100	45200	51800	34700	49300	35300	50400	29000	50200	25500	40600	21700		
3	51100	30200	51800	34600	49700	36100	50500	27200	31800	28300	48000	22300		
4	51300	30800	51900	34500	50200	35900	51300	27200	28500	26600	47300	22600		
5	51300	30600	52400	35300	50700	34600	48800	27200	50600	26900	46100	21500		
6	51100	31200	52500	36300	51000	36100	49600	26900	50500	26700	46700	20500		
7	50000	31400	53000	35600	50700	36400	51300	25900	45300	25800	46700	18500		
8	50300	32200	51500	35800	51600	36500	51100	25100	47000	26000	45600	17700		
9	49300	32000	51500	35600	51800	36600	50500	20100	49600	26100	43500	21400		
10	50600	31600	51400	35400	51800	39200	51100	16300	50600	23200	46100	22700		
11	51300	33700	51900	41700	50700	36300	48900	14900	49500	18000	46100	21500		
12	51400	33700	52100	35500	37000	35900	51000	24000	51900	19100	48000	21300		
13	50400	33700	52900	34900	49800	36600	51000	24900	48500	17400	46700	22300		
14	50700	33500	52600	35100	51100	36900	49600	25000	49600	17100	45200	22600		
15	51600	33800	52400	34600	51200	36400	52000	24400	50300	19200	47100	22400		
16	47000	33100	52200	35400	51500	33600	52100	24700	50200	22300	47400	15600		
17	50500	34200	52100	35500	51500	33800	51900	23300	49700	15900	45600	15000		
18	51500	37000	52100	35300	50900	43400	51900	23000	49100	15300	18700	14900		
19	51600	37800	51900	35300	50800	31600	51900	23200	49800	15300	45600	16300		
20	51500	37200	51900	35500	50700	32200	51200	50500	49600	15900	44900	16200		
21	51200	35900	51600	34500	50800	34000	51100	24200	49900	15500	44700	16000		
22	51700	35000	51600	34100	51200	33300	51500	24000	49100	17000	41700	16600		
23	51900	35100	51500	33000	51500	28200	51600	23200	47000	16600	45500	16600		
24	51900	34700	49800	32700	51500	42000	51500	23500	49100	16500	45000	16200		
25	51300	34600	49600	34200	50300	26000	51400	25100	50000	17400	44100	15800		
26	51100	34300	49600	43300	50400	25800	51500	25800	49400	17800	45100	15600		
27	50800	34600	49400	37300	49600	26500	51300	26500	49000	18700	44900	15900		
28	51100	38400	49300	41900	49000	25600	50900	25700	48800	21300	19400	17500		
29	51700	51200	49200	34200	49400	25000	49100	26400	47300	16500	18600	18000		
30	51600	36900	49200	35100	50200	26700	51000	25800	50000	17400	44100	17200		
31	51900	34900	---	---	50400	27300	51100	26500	50000	17400	44100	14700		
	51900	30500	52900	32700	51800	25000	52100	16800	51900	15300	48100	14700		

United States Department of Interior - Geological Survey  
Process Date is 05-03-84  
Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 302335 Longitude 0833116 Drainage Area Datum State 12 County 091  
Source Agency USGS

Specific Conductance (*Micromhos/cm* at 25 Deg. C.), Water Year October 1982 to September 1983  
Sampling Depth 16.00 (ft.)  
Provisional Data

United States Department of Interior - Geological Survey  
Process Date is 05-03-84  
Station Number 302335086311601 East Pass Choctawhatchee Bay at Destin, FL Estuary  
Latitude 30°23'35" Longitude 086°31'16" Drainage Area Datum State 12 County 091  
Source Agency USGS

Specific Conductance. (*Micromhos/cm* at 25 Deg. C), Water Year October 1983 to September 1984  
Sampling Depth 16.00 (ft.)  
Provisional Data

US Department of Commerce  
NOAA Coastal Services Center Library  
2234 South Hobson Avenue  
Charleston, SC 29405-2413



NOAA COASTAL SERVICES CENTER LIBRARY  
3 6668 14102 0307